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ABSTRACT

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The study purports to qualify the psychological information value of autonomic-somatic activity, the source of the traditional dependent variables of psychophysiology. This is done by verifying their ability to show situational specificity not only as response to realized events but also on the basis of mere mental representations of these events via anticipation. The demonstration of effects of overt situational demands is made by comparing the immediate responses produced by varied critical events. The situational specificity of the anticipatory response patterns is studied by recording the pre-event patterns of these same events while varying the advance information about them.

Skin conductance, pulse amplitude, blood volume, heart rate, respiration, pupil dilation and three EMGs (flexor, frontal and orbicularis oris) were recorded from 112 Ss in two-event conditions in which the first event offered a varied amount of information about the second, critical event. Six types of critical events (sensory, motor and two cognitive tasks and two stimulus types) were presented in semirandom order to four groups of subjects. The amount and type of advance information given to the groups as the first event was systematically varied.

The six events were shown to produce event-specific patterns. The most pronounced contrasts were between the main types of events, viz.cognitive, motor and sensory events. This specificity appeared already in the immediate responses to the first event in the most informed group and showed similarity to the responses produced by the critical event itself. Specificity also increased as a function of the amount of advance knowledge. This made it possible to examine it as an expression of anticipation. The advance information had an effect also on the event-produced response pattern, which verifies the phenomenon called preception by Lykken. Its known empirical manifestations were replicated. Several new aspects of the preception phenomenon and the evidence about anticipatory physiological responses and their patterning were introduced for discussion for the first time.

Anticipation. physiological arousal. psychophysiology. situational specificity. activation. autonomic response patterns. autonomic response specificity. preception. preparation. set. skin conductance. heart rate. pulse amplitude. EMG. respiration.

PREFACE

The present choice of problems and experimental work focuses on showing the psychological relevance of the psychophysiological research strategy. The search for this relevance has led me to concentrate on the study of situational (or demand-) specificity of physiological activity and on the modification mechanisms of related arousal dynamics. Thus the objects of the present empirical observation are the event-related patterning of physiological responses produced by varied psychological events and - I would say, first of all - those forms of this activity which manifest anticipation of these events.

The background for the present theoretical view and problem setting is based on earlier studies of which the most directly related are Lyytinen, 1970, 1974, 1975a, 1975b, 1978, 1981 and 1983a as well as on reviews of literature and of our data (Lyytinen, 1974, 1975c, 1982a, 1982b, 1982c, 1983b, 1984). Additionally many studies done together with students have had a strong influence on choices made in the present thesis.

I am indebted to Professor Martti Takala and Professor Isto Ruoppila for their continuing support of my work. I thank them and also the present Head of the Department of Psychology, Lea Pulkkinen also for their tolerance to my perseverance in occupying myself with 'background' research rather than concentrating on my dissertation during the many years I have worked in the department chaired by them. My thanks go to Professor Carl Hagfors who introduced me to psychophysiology. He also read the present manuscript giving valuable comments. I would like to express my appreciation to Professor Risto Näätänen for his encouragement of my work. He has read my recent papers including the present manuscript and from him I received motivating comments which affected the direction and maintenance of my interest in the focus of the present thesis. I am also indebted to Professor

Joseph Campos for his encouraging comments about my earlier work and his wise advices during my visit to his laboratory at the University of Denver.

Important support has come from several of my colleagues, coworkers and students. I wish to thank especially Ph.lic. Tapani Korhonen with whom I have had extensive and stimulating discussions about psychophysiology. The available space would not suffice for cataloguing all of the others; my thanks go to all of them.

A debt of gratitude is owed to the Finnish Academy and the University of Jyväskylä which have supported my work both by allowing me the opportunity to concentrate on research, and by providing the resources needed in it and for visits to laboratories and conferences related to psychophysiological research. Without all this the present work would not have been possible.

I am grateful to Matti Hinkkanen who has assisted me in different phases of data analysis over several years. I thank also Auli and Ken Batts for checking the English of this report and Ken Batts also for drawing the Illustration 1. My thanks are due to Jyväskylä Studies in Education, Psychology and Social Research for including my work in their series of publications and its editor Ph.D. Sirkka Hirsjärvi for her editorial advice.

My deep gratitude belongs to my parents, Kalevi and Elina Lyytinen, for their support to my orientation to scientific work and to my family for continuing this support later. Not only this study, but many of the related earlier works have required a lot of the potential free time normally available to a father to spend with his family. I am sure that few women outside the scientific community would have shown as much understanding as has my wife Paula. Without her support the sacrifices required of my children Anu and Sanna-Mari would have been intolerable to me. My warmest thanks go to them.

Jyväskylä, December 1983

Heikki Lyytinen

CONTENTS

1. INTRODUCTION

A basic methodological characteristic of the traditional psychophysiological approach has been its concern with the unobtrusive and moment-by-moment monitoring of the two (psychological and physiological) levels of concomitant processes constituting the psychophysiological reality. The research has had two additional features: First, the psychological sphere, which is handled as an independent variable (eg. Stern, 1964; Hasset, 1978) is manipulated mostly via immediate stimulus effects (see for explicit comment: Sternbach, 1966, 3 and Andreassi, 1980, 6) to create externally objectifiable variables to represent the psychological reality. Second, the unity between the psychological and physiological levels is construed by conceptualizing the physiological changes with psychological labels like ´arousal´ or ´orienting reaction´.

There are problems and limitations both in sampling of psychological phenomena as immediate products of external stimuli and in the constructs via which the consequent physiological responses are interpreted. The concentration on the study of immediate stimulus-effects excludes essential features of human behavior. At least partially due to this emphasis, the potential merits which the moment-by-moment recording might offer for shaping process-like features of the studied phenomena have not been realized. The insufficiency of theoretical means and constructs for modelling the relations between the two levels or aspects of the object characterizes especially the research which uses traditional autonomic (ANS) and somatic (SNS) nervous-system variables. The interpretation of psychophysiological results have been almost exclusively founded, if not explicitly at least implicitly, on some form of restrictive, mostly unidimensional arousal (or attention) construct.

Both from a physiological and psychological point of view these methodological emphases can be seen as needing updating. Lyytinen has defended this argument in recent review articles (1982a,1984) and has published preliminary experimental evidence (1982a, 1983a). The present paper purports to demonstrate empirically the insufficiency of these emphases in psychophysiology. Evidence is introduced for psychologically interesting phasic physiological changes which are not immediately stimulus-elicited and which also display multidimensional, multivariately informative 'arousal'.

1.1. Functions of the autonomic nervous system

The autonomic nervous system has at least three functions: protection, activation and integration (Brooks, 1979). All these functions contribute in the organization of bodily resources for coordinated preparedness in coping effectively with the situational demands or requirements. The coping takes place either (a) purely reflexively or according to results from different levels of analyses of the demands as these can be perceived or anticipated via (b1) conditioning or (b2) cognitive extrapolation of the future. Hence, all these functions can be seen to be in someway future-oriented.

The protective function refers to processes which should be initiated before or concomitantly with the event against which protection is needed. The activation function of ANS means mainly the adjustments via which visceral activity supports central functions and somatic behavior, or psychologically speaking, cognitive, motivational, emotional, and motor processes. The activation and integration functions are intimately intervowen as all their results appear on different levels of nervous activity and include the maintenance of cortical tone in relation to the action orientation prevailing at the time (Luria, 1973) and related maintenance of optimal bodily preparedness. ANS activation has countless bodily manifestations; it for instance affects sensory receptors, activates endocrine glands, shunts blood, affects heart-pumping action and releases nutrients from storage (Brooks, 1979). All this often begins by promoting anticipatory, preparatory action (Brooks, 1979).

In its third, integrative function ANS has a primary task as organizer of the bodily resources for action. This takes place through the direct control of higher central processes which mediate the integration in time, the use of past experiences for future preparedness. Integration appears also in the fact that ANS innervates all tissues of the body and is involved in all its reactions. This produces the integrated totality of bodily responses essential to effective behavior (Brooks, 1979).

It is in the interest of psychophysiologists to specify and verify how an understanding of these functions helps to find from the multitude of ANS-activity those features whose contribution in realization, control and/or support of psychologically relevant phenomena can be explicated and their information value benefited from for psychological study.

1.2. Arousal

Thus far the main common denominator of psychophysiological study has been the hypothetical dimension called arousal or activation, specified originally in the classical activation theory (Duffy, 1951, 1957, 1962, 1972; Freeman, 1948). It has been thought to reflect the ´energetic´ aspect of behavior, not at all or at best only secondarily any ´directional´, ie. primarily task/stimulus-specific aspects of activity. This theory has not passed a thorough empirical test even as a rough formulation (eg. Lacey, 1967). Current evidence speaks strongly against the contention that unidimensional activation or arousal conceptualization can exhaust the psychologically relevant information ANS- and related SNS-activity may offer.

There are both empirical and theoretical bases to emphasize the multivariate nature and specificity rather than a univariate nature and non-specificity of the phenomena measured in terms of arousal. Much empirical data support the multidimensionality of relevant ANS responsivity in relation to psychologically interesting phenomena like attention (eg. Lacey, 1972), or orienting reaction (eg. Barry, 1979) and also of behavioral manifestations of arousal (eg. Thayer, 1970, 1978; Hamilton et al. 1977). Differentiations within arousal phenomena have been specified neuropsychologically (eg. Luria, 1973; Pribram & McGuinness, 1975), neurophysiologically (Routtenberg, 1968; Gray, 1977; Vanderwolf & Robinson, 1981; Pribram & McGuinness, 1975) as well as psychophysiologically (eg. Fowles, 1980).

One way to show the multivariate nature and specificity of arousal is to analyse its sources as Luria (1973) has done. He differentiates three main sources. The first consists of the metabolic processes which maintain the internal economy of the body as a primary homeostatic and vital source of activation. Already within this lowest source, which also contains a developmentally advanced level including the complex instinctive behavioral patterns, there exist clear separations between different types of arousal regulations. The internal economy is thought of as being controlled mainly on the hypothalamic level, while the instinctive behaviors have their specific functional paths within for instance the reticular formation system. Related arousals are based on multiple neural complexes both physiologically and anatomically and also have multiple measurable manifestations both physiologically and behaviorally (eg. Siegel, 1979).

The second and third sources of arousal are in operation in a situation which presupposes some change in the maintenance tone of the nervous system. The second source is connected with the arrival of stimuli from the outside world and leads to the production of activation manifested as an orienting activity. Its tonic level is modulated reflexively by the continuous flow of external stimulation and it forms a further level of maintenance arousal. Novel and significant changes in this sensory flux elicit phasic orienting responses mobilizing the organism to meet possible challenges from the environment. The physiological regulation and manifestations of these two sources clearly differ and so also do the levels of arousals controlled by the sensory sources. Evidence for their different physiological transmissions within the reticular formation has been available for a long time (eg. Sharples & Jasper, 1956).

The third source of arousal is the most interesting one from the point of psychological relevance. It functions according to the demands human subjects can address to themselves. By using past experiences stored in the memory, human beings are capable of forming intentions and plans involving the future. Thus in this case the stored experiences and the actual sensory information synthesized in relation to earlier knowledge rather than mere immediate external stimuli constitute the ′stimulation′. On the basis of this synthesis bodily resources are allocated for preparation according to the anticipated demands on the control of higher nervous processes. A much broader vertical organization of different levels of brain processes form the physiological basis of this source of arousal. Significant influences come in this case via the descending fibres running mainly from the prefrontal cortex down to nuclei of the thalamus and brain stem (Luria, 1973; Pribram

& McGuinness, 1975).

For the present study, the most important distinction between the sources and manifestations of arousal can be posited between arousal responses determined by immediate stimuli, or effects originating on the level of a ´first signal system´ - to use the Pavlovian terminology - and those arousal activities reflecting and modulating the internally effective, memory-based contents and related action orientation. (These contents may be rehearsed when triggered by external stimuli, but supposedly immediate stimuli as such do not have much to do with the composition of the related arousal pattern). This distinction is near to that prevailing between Luria´s second and third sources of arousal.

An informative further distinction can be found in a classification made by Pribram and McGuinness (1975). It is not based on sources of arousal but on differences in the neurophysiological mechanisms which regulate arousals. They differentiate physiological systems controlling ´arousal´, ´activation´ and ´effort´ functions, respectively, as they call them. Arousal refers to involuntary, phasic responses to input, ie. something resembling the phasic orienting reflex in Luria´s terminology. Activation is like Luria´s tonic orienting activity when defined as the physiological state of maintaining a set to continue ongoing behavior. Effort refers to coordination of arousal with activation via exertion of voluntary control.

None of Pribram´s components is directly comparable to the original activation level concept formulated by Duffy or other related developments emphasizing the tonic, or on the other hand the homeostatic aspect of ANS-activity as studied eg. by Wenger (1966). Pribram´s tripartite arousal conceptualization is more relevant for the study of phasic changes which are at the focus of the present interest. The tonic and hormonal processes related to activation and arousal remain outside the present concern.

Psychophysiological research has thus far been mainly concerned with the arousal elicited by the second source of Luria´s typology. The directly reflexive forms of the responses elicited by much studied unconditioned aversive (like shocks) and related conditioned stimuli or orienting reactions elicited by novel stimuli both appear mostly as increases in general, non-specific preparedness for flight or fight, ie. sympathetic autonomic arousal. Especially in the earlier literature there are, however, examples also from more specific forms of preparatory arousal. Among these are the salivary responses studied by Pavlov, who observed that such conditioned or anticipatory responses are specifically composed according to the prevailing demands (ie. are secreted in appropriate chemical composition for digesting the specific food given as UCS).

Of value to psychology are, clearly, not only those forms of physiological activities which have been most repeatedly studied, ie. ´arousal´ in Pribram´s sense or those modulations of arousal which originate from the second source in Luria´s terminology (if these as such can be differentiated at all in human subjects), but also and especially the ´higher´ forms reflecting the third source and voluntary effort.

To sum up the background for the present set of problems: psychophysiologists measure physiological changes in order to increase understanding of psychologically relevant phenomena. The typical implicit variable manipulated for observing such changes in the ongoing physiological activity or behavior has consisted of ´energy´ or ´information´ as obtained via external stimulation. Attempts to achieve this relevance have consisted of conceptualizations of the related independent and dependent variables accordingly. Thus far the most common conceptualizations have reduced the independent measures to variables like intensity, novelty etc. and arousal to a single dimension of variation (sympathetic activation). The directional aspect of the information which the stimulus may offer has not been a central independent variable and similarly the specific composition of arousal (pattern) has not been a central dependent variable.

In the present study, an attempt is made to demonstrate how it may be psychophysiologically meaningful to reconceptualize both ´stimulus information´ and ´arousal´ to account more specifically for the directional effects of information and consequent specificities of arousal patterning. It will be shown that phasic arousal-phenomena constitute multivariate forms of physiological activity which are not necessarily nonspecific to a significant extent. Informational influences on arousal phenomena are expected to have a multilevel nature. The highest levels tend to dominate via their property to specify the goal of the activity. The consequent activity demands of the situation make the organism prepare specifically for it and the manifestations of physiological arousal are patterned accordingly. The situational demands are specified either reflexively, through conditioning, or by cognitive, intentionally initiated integration of earlier habits. The peripherally manifested arousal on the autonomic and somatic level follows this specification automatically.

1.3. Anticipatory arousal*

The integrated totality of psychological processes participating in the demand-specification for future activity has been called ´anticipation´ (Lyytinen, 1982a,1984).

If enough time is given for observing the physiological changes occurring between the task or demand specification and the realization of the activity, this physiological activity may offer psychologically useful evidence about anticipation. In the first place these manifestations may offer information about internal processes included in anticipation.

From this perspective, situational demands unite the physiological and psychological spheres. The externally given and/or internally represented stored information initiates and directs a search of the demand characteristics of the situation which specify the subsequent modulation of arousal. Every externally elicited deviation from the automatically ongoing course of behavior means production of an orienting activity. It calls upon mental resources to continue from the question ´what was it?´ to ´what is to be done?´-type processing (Kvasov & Korovina, 1965). Thus the activity moves from a nonspecific readiness to a more focused and specific, demand-related preparation for the immediate future. The latter preparation relates to the intentions and plans. However, it has been customary to study such orienting problems almost exclusively from the first point of view. Orienting is thought to be a nonspecific arousal response (Sokolov, 1963) which is not composed on the basis of the contents of the given or stored stimulus-information. Orienting stimulus is seen as a trigger and the orienting response as some immediately elicited change which is not affected by the specific response demands the stimulus or the condition may pose.

A further directly related bias in the psychophysiological research has been its almost exclusive concentration on the supposedly ´pure´(ie. reflexive) conditioning constructs in explaining the modulations reflecting contingency learning. This has fixated the psychophysiological study on easily replicable UCS-conditions and therefore other, psychologically probably more inter-

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* Very little recent data exist about anticipatory arousal as studied experimentally outside conditioning research (in terms of conditioned reaction). The few relevant studies are described in Lyytinen (1984) and summarized also in the context of evaluating the present findings in discussion. Only the necessary background views relevant for understanding the present approach are mentioned here. (continues, page 8).

esting types, of correlations between the situational requirements (demand characteristics) and concomitant physiological processes have received less attention.

Empirical data show that only in very specific and exceptional conditions does any form of future oriented responsivity (eg. CR-like responses) appear in human subjects (at least in the laboratory) totally without participation of at least partially conscious perception of the situation, ie. via pure conditioning (see eg. Brewer, 1974). Although in natural behavior reflex and learned automaticisms control and coordinate complex behaviors without conscious participation on the level comparable to that observed in laboratory conditioning studies this does not mean that even these automatisms or related conditioned patterns of ANS- and somatic behavior would run totally without cognitive controls. A psychologically most relevant component of this activity is controlled by a higher level, which parallels intentions initiating the goal directed programs for realization of a more or less complex act. And this tends to make these higher-level processes, together with the concomitant more peripheral executions (automaticisms), important objects of psychophysiological study. Autonomic responses may be modified via a ´pure´ conditioning mechanism, but such a modification constitutes only one, limited and not easily accessible level of functioning into which

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A context of psychophysiological study in which anticipation has returned to the center of interest has been the evoked potential research. Within this research one influential recent approach led by Näätänen has taken anticipatory processes for granted and also explicated these with experimental data (Näätänen, 1970, 1975, 1977). Näätänen considers anticipation to have a mediatory role between arousal and attentional processes so that anticipations, by having their manifestations via arousal, mix with those of attention. The focus of his interest has been in the problems these anticipatory effects - which he assumes quite nonspecific - introduce in the specification of the evoked potential correlates of selective attention. This falls outside our present interest and is not considered further here, but shows how concretely anticipatory processes may be intervowen with eg. attention. Other Finnish researchers have also been interested in anticipatory processes although it has been not so much present in the recent international literature. Thus Takala (1969) has underlined the role of anticipation in activational processes. The experimentation led by him has demonstrated the potential value which the physiological recording of anticipatory processes may offer for the investigation of motivational dynamics. The studies of Takala and Näätänen concerning anticipation have been one source of inspiration to direct my interest in this aspect of arousal processes. The emphasis of the present approach has been, however, more in the methodological and methodical problems related to anticipation research and first of all in their psychophysiological, rather than psychological or motivational aspects. Nor does the experimental data which constitutes its explicit empirical background come from the evoked potential study represented by Näätänen. The antecedants arise first of all from the conditioning research with which I have become familiar also through my own research (1970, 1974, 1975a, 1975b 1975c).

effects of 'higher control' very easily intrude. Its study contributes mainly to the understanding of emotions and psychopathology which is outside of the present central concern.

One emphasis of the present experimental approach is on verifying the contention that autonomic and somatic peripheral changes function as supportive and integrative routines which are subordinated to the highest momentarily effective level in the hierarchy of behavioral/experiential controls. Therefore it is suggested that 'anticipation'-concept better makes understandable many of the physiological pre-event changes studied in psychophysiology than concept like 'conditioned' response. Conditioning is one of the mechanism which, however, can be used to describe the process on which anticipation may be based, as told above.

A minimal empirical evidence needed to support a contention that the meaningful level for examining autonomic response modification as something based on cognitive rather than more reflexive phenomena could be to show experimentally that already the pre-event ANS- and SNS-responses display consistent patterning corresponding to advance information given to the subject about demands for activity. Substantive evidence would not only support this general contention. Additionally the related compositional characteristics of the observed response patterns might offer interesting information about anticipation and thus introduce theoretically useful data.

Little is known about the relationship between these 'higher forms' of control and autonomic-somatic activity because of the lack of theoretical tradition to approach the problems of psychophysiology from this direction. Some applicable evidence comes from biofeedback research, whose data proves that modifications of 'involuntary' ANS-responses, not belonging to the natural unconditioned repertoire of supportive or integrative form of ANS-activity, can be acquired as motor or mental habits via a step-wise rise of control to voluntary forms (eg. Brener, 1974).

The general hypothesis of the present paper is that autonomic activity is to a great extent controlled from higher levels and follows demands for changing or maintaining the bodily activity or cortical tone according to the situational requirements as specified by these higher processes. Autonomic activity can reflect how the subject has internalized the situational demands already in anticipation of the potentially required activity. This it does without obtruding or confounding them as eg. verbal measures would very probably do.

Two characteristics of phasic physiological activity are distinguished for study. These are: (1) the event-produced activity as it appears as a multivariate, and supposedly demand-specific pattern and (2) the corresponding pre-event pattern recorded from subjects who have been given varied amounts of advance information about the event. The first represents immediate, stimulus-driven activity which is relatively more externally controlled. The second represents memory-driven, internally controlled anticipatory activity.

1.4. The experimental paradigm for the study of demand-specificity of physiological arousal patterns

To make direct access to these characteristics possible, experimental conditions should be created which allow the demand-specificity to appear and the manipulation of demands with and without immediate stimuli as their informational basis. To preserve direct comparability, the same events should be critical stimuli for both. Such a context can be realized by comparing pre- and post-activity to the same advance-informed critical event. Advance knowledge allows an internal representation of the event for formulation of response demands of the critical event and works also as a trigger for the related memory driven informational basis from earlier experience. Comparison of physiological pre-event activity between groups differentially informed in advance about the future critical event would offer an opportunity to explicate the effect which such a memory-based information can have on the physiological measurements. Such an experimental setting makes it possible to compare psychophysiological responses based on sources of two different control levels of demands - viz. realized/external and anticipated (imagined?)/internal - as determinants of the arousal patterns.

The variation of information about the future critical event is made by using a two-stimulus paradigm, in which the first stimulus (S1) offers varied amounts of information about the second (S2), the critical stimulus or event actualizing the presupposed activity. The informational manipulation and the aim of observing presumed specificity makes it necessary to use several different types of S2-events. This variation is made on a within-subject basis to allow sufficiently sensitive comparability. The sampling of the critical events is intended to be representative in relation to the present knowledge about demands presumably provoking differential arousals. The present sample includes sensory, cognitive and motor tasks as well as external UCS-like stimuli (loud tone and shock).

To assure the possibility of observing multidimensionality of arousal-related physiological changes and specificity of patterning, a representative sample of psychophysiological measures is selected. The present choice of measures includes skin conductance, blood volume, pulse amplitude, heart rate, respiration, pupil dilation, and three electromyographic variables: muscle activity from orbicularis oris, frontal and flexor muscles. The somatic (SNS-) variables are included because they are thought - following the tradition of psychophysiology - to be intimately associated with the arousal dynamics.

1.5. Components of pre-event arousal

An aspect of further interest for specification is the temporal pattern of pre-event activity as it appears in the interval between the critical event (S2) and the information given in advance (S1). An analysis of literature reveals that two types of phenomena may be separable during this interval. Related research has produced a psychological conceptualization of processes or responses appearing during this interval (relevant evidence has been reviewed in the context of conditioning research by Stern (1972) and Lyytinen (1970, 1975c)). These are ´orienting reflex´ elicited by any new or significant stimulus (as specified by Sokolov, 1963) and ´anticipation´ (Stern, 1972) ´expectancy´ (Epstein, 1973) or ´set´ (Grings, 1960; Gibson, 1941) thought to precede an informed event.

The role of pre-event activities was studied already in the early psychophysiology eg. in terms of ´set´, by its pioneers like Davis (1946), Darrow (eg. 1934) and Freeman (1939). The related constructs were, however, soon displaced for several decades by the behavioristic emphasis on external contingencies as the only determinant of behavior. In some compromised forms these concepts have, however, been applied also during the most active behavioristic era by psychophysiologist like Grings (eg. 1960; 1973) and Walter & al. (1964). Theoretically this point of view has not been totally neglected. In fact it has produced one of the most interesting attempts to create a theoretical basis for psychophysiology (Germana, 1969). Approaching from the perspective of ´central efferent´ theories Germana proposes that a) central (ie. CNS) activities give rise to experience and to the specific autonomic responses which occur in the periphery, b) these central activities constitute the organization of autonomic responses and c) **central efferent organization** is reflected at the periphery (in ANS and SNS) as an **anticipatory**, preparatory state. For Germana the essential meaning of the autonomic-somatic measures on which psychophysiology is based is associated with their value as reflectors of the central processes in terms of anticipatory and preparatory processes.

Following the tradition of conditioning study, a long interstimulus interval (ISI) was used in the present study for making it possible to observe the two types of pre-event activity, viz. orienting and anticipatory responses, shown there to be potentially separable temporally. The immediate response to the new informative stimulus may be seen as an orienting response by definition, and the subsequent ´preactivity´ may be supposed to belong to the preparatory processes for the critical S2-event.

Are these two phases of approach to a future event in someway different? I assume on the basis of the above arguments that the pre-event responsivity is specific to the expected event. The orientation reflex is thought to be a nonspecific response including preparatory activity in a general form, ie. increased sensitivity of receptive organs and increased preparedness of efferent executors (Sokolov, 1963). Thus there is a basis for expecting empirically verifiable differences between those two phases of preparation for the immediate future: these two response patterns should be differentially specific to the future event. As an additional differentiating feature the two phases can be expected to differ in their tendency to show reduction as a function of repetition of trials. Orienting reaction is known to habituate (Sokolov, 1963). Preparatory activity would rather show further development and refinement of pattern during trial repetition.

1.6. The relationship between pre- and post-event arousal

A central problem of the present study is the relationship between the supposed preactivity resulting from the basis of advance knowledge about the immediate future and responses elicited by the critical (S2-) event itself. The preactivity as defined above is hypothesized to be specific to the future event and thus would be thought to model the post-event pattern (Lyytinen, 1982a, 1982b).

Lang (1979) has documented by a review of empirical data how imaginary emotional involvement is accompanied by autonomic-somatic patterns similar to their real-life emotional equivalents. Analogously, anticipation of specific stimulation or performance can be supposed to manifest itself as ANS-SNS activity which mimics that observed as a response to their real experience or execution. Thus mental planning of (for example) a specific somatic act would be accompanied by autonomic preparatory activity which resembles in form that prevailing during its real execution. Similarly, preparation for a specific sensory experience probably manifests itself as an autonomic-somatic involvement which resembles activity appearing during the experience of the real stimulus. All this is compatible with the physiological functions of ANS as specified above.

1.7. Arousal and performance

An important aspect of arousal is its relationship with performance. The task-related physiological activity both during and in anticipation of it is interesting also from this viewpoint. Arousal-performance relationship has been mainly studied from the perspective of activation theory. In this theory activation has been identified with a dimension of behavioral intensity (eg. Hebb, 1955), level of sensory input (eg. Hinde, 1970; Easterbrook, 1959) or general preparedness for activity (eg. Duffy, 1962). Empirical studies have been made for finding curves which describe the relation between such a dimension (based on one or another of these conceptualizations) and the level of related task performance (eg. Hokanson, 1969; Malmo, 1959). Näätänen (1973) has presented a detailed criticism of such a reduction which would have one correlate two such complex phenomena with a single function. He proposes that arousal patterns appropriate for performing a task effectively should be specific to it, ie. to match with demand characteristics included in the related task-performance. This view is compatible with the one presented above and is central to the whole thinking on which the present approach is based.

Although the main focus of the present experimentation is not in the arousal-performance relationship, it offers contexts which allow a preliminary inspection of the relationships between task-related arousal responses and performance in the task. Of special interest are the possible relations between anticipatory physiological changes and performance level of the subsequent task-performance. The last evidence may have value in the analysis of the functional role of the anticipatory physiological arousal.

1.8. The ´preception´ phenomenon

A related further question of psychophysiological interest is as follows: Is the future expected task or experience internally represented in such a way that it also has some role in the determination of the response to the critical event, ie. does it modify the typically measured post-event response?

In fact advance information about an event has been shown to have an effect on the response which the event produces. Lykken (1962) has formulated a ´preception´-hypothesis which concerns such a modification of the response to a stimulus as a function of advance knowledge. The so called ´negative preception´ hypothesis holds that ´when an aversive stimulus is made predictable in time the subject is able to inhibit his arousal response to that stimulus and thus reduce its aversiveness or impact´ (Lykken & Tellegen, 1974). This hypothesis has gathered ample empirical support (Averill, 1973; Epstein, 1973; Lykken, 1959, 1962; Lykken, Macindoe & Tellegen, 1972; Schell & Grings, 1971; Waid, 1979) although only with single arousal measures, and the total picture about these informational effects is in dispute (Furedy, 1975).

In the present context this hypothesis is relevant because it refers to a functional relation between the pre- and post-event activities, ie. to one of the main concerns of the present study. From the empirical point of view it is interesting also because the present experiment includes concomitant measurement of several such ´arousal´-variables which have thus far not been tested in relation to Lykken´s hypothesis.

Pre- and post-stimulus changes measured in a context of pre-warned noxious stimuli can be expected to be interrelated on the basis of the ´classical´ interpretation for the operating mechanism of a preception phenomena. Perkins (1968) regarded such informational control as having its effects via ´adaptive preparation´. In the case of skin conductance, which is empirically the most widely validated response manifesting preception, the pre-event activity could logically be expected to reflect such an adaptive preparation which allows the organism to prevent injury to the skin if it is in danger of being exposed to a noxious stimulus. This means that the preparatory activity already results in a sufficient amount of protective media on the skin to prevent injury thus making the later activity needless (Dengerink & Taylor, 1970).

Champion and Hodge have recently (1983) published an elegant demonstration of the validity of such adaptive information control. They derived their research hypothesis from skin-conductance responses to shocks of different types. According to Ohm´s law it is possible to predict that the physical intensity and thus supposedly also an impact of a constant voltage shock would be reduced by a fall in skin conductance while the physical intensity of the impact of a constant-current shock would be reduced by a rise in skin conductance. The hypothesis was supported by their data. When constant-current shocks were presented skin conductance tended to increase while an opposite change was observed when the subjects were exposed to constant-voltage shocks (Champion & Hodge, 1983).

This result is not only compatible with a preception or preparatory-response hypothesis but also shows how ANS-responses are modified according to adaptive demands because they are immediately reinforced biologically. When adequate physiological changes precede (ie. are anticipatory to) impacts of noxious effects (against which protection is needed) these may thus assure the protection of the integrity of bodily functioning.

1.9. A summary of the problem setting

The present experiment has three general aims. The first is to evaluate the information value of the typical phasic responses recorded in psychophysiology when the responses are not scored and interpreted in terms of a single-dimensional arousal construct. This is made by proving the event-specificity of ANS-SNS response patterns by demonstrating conditions-specific contrasts between them.

The first hypothesis (1) is that ANS-SNS patterns display qualitative event-specificity. The forms and manifestations of this specificity as they appear in the selected six experimental conditions and nine physiological variables constitute the first problem.

The second aim is to show that this specificity is understandable by analyzing the ANS-SNS activity as a function of event-related demands rather than trying to explain it in terms of eg. mere ´energetic´ responses to the subjective or objective intensity of external stimulation or of related behavioral intensity. It is thought that such a demand-specificity can be proved as far as it can be shown that a) response patterns are specific to events, b) the responses show this specificity also during the anticipation of the events and c) the event-produced and anticipatory response patterns are interrelated.

It is presumed that the same processes on which mental cognition is based also cause the phasic ANS-SNS pre-event patterns to exhibit goal-directedness and thus to display specificity according to the requirements which the expected future includes. Psychophysiologically their most interesting manifestations are thus dependent on the total information the subject has available about the immediate tasks he addresses to himself or stimulation he can expect to occur and thus prepare for. Two hypotheses are derived for testing the empirical validity of this thinking:

Hypothesis 2: Pre-event ANS- and SNS-responses disclose increased specificity as a function of the amount of advance information the subject has about the critical event.

Hypothesis 3: The specific pre-event activity resembles the activity produced by the critical event itself.

The evaluation of forms and manifestations of the pre-event ANS-SNS activity as a function of the studied conditions and physiological variables constitutes the second problem. Special emphasis is given to the differentiation of temporal components in the pre-event responses. Two separable components can be predicted to be manifest during the S1-S2 interval. The first, immediate response to the S1 should behave like an orienting response, ie. habituate as a function of trials and be nonspecific in nature. The second, anticipatory response preceding the S2 should exhibit specificity according to S2 and increase rather than decrease as a function of trial repetition.

The third general purpose of the present experiment focuses on the evaluation of the effect of the advance information on the 'arousal' elicited by the event itself. A generalization from the preception research leads one to present a further hypothesis:

Hypothesis 4: The post-event activity, ie. the response to S2, is affected by the advance information. Its most explicit form appears in the reduced responsivity to prewarned aversive stimuli like shock. The forms and manifestations of the effects of advance information on the responses to the critical events (S2) constitute the third problem.

The contexts related to the second and third problem areas allow inspection of modification mechanisms of ANS-responses. To what degree are these reducible to conditioning or habituation? This question, which has motivated the present problem setting, is dealt with tangentially in the evaluation of several aspects of the present results.

2. METHOD

2.1. Subjects

A total of 112 male students from the Vocational School of Central Finland served as subjects in different parts of the study. Their age range was 17-22 years. 12 of them participated in the preliminary experiments only, during which procedural aspects were developed further and tested. Data of four subjects were totally disregarded for different reasons, mainly because of instrumentation problems which disqualified large parts of the data. Six subjects constituted a specific control group. From the remaining 90 subjects (Ss) the data of 80 Ss were used in those complex statistical analyses where equal groups (a´ 20) were needed. Because some subjects had single trials with missing data the exclusion of additional subjects for this equalization was realized according to the technical faultlessness of the total data recorded from the subject. Subjects were volunteers and were paid for participating in the study.

2.2. Instrumentation

2.2.1. Control and presentation of experimental events

The timing and control of the experimental events were realized using electronic circuits constructed for this specific purpose. Timing was realized mainly with monostable multivibrators with Schmitt-trigger inputs (SN 74121N-circuits). These timed the starts and durations of the stimuli and intervals between them as well as the trigger pulses and prestimulus delays needed for controlling the computer scoring of the data. The choice of the trial type (condition) could be preprogrammed with a device based on flip-flop circuits for sequencing trials in twelve trial sets. The intertrial intervals (ITIs) were timed using a random number generator to get the ITIs for this sequence to vary randomly within a specified range.

The main stimulation was based on slides. These were presented with two 35-mm Leitz Pradovit projectors having 100 mm Leitz Colorplan lenses. Slides were projected from an adjacent instrumentation room to a screen in front of the subject through soundproof glass and the screen. Auditory stimuli were produced using Taylor and Ediswan oscillators (model 191A and type R .666, respectively). Tones and instructions were fed into AKG K 158 binaural headphone & microphone combination via which all communication between rooms was run during the experiments. Auditory signals were amplified in two channel Tandberg 4000x Crossfield tape recorders, which made also possible the recording of the needed parts of the communication. Shock-stimulation was realized using a constant current stimulator, which allowed the maintenance of the physical shock-intensity independent of changes in the skin resistance between the stimulating electrodes.

The tone intensities were measured with a Philips PM 6400/01 instrument and light intensities as reflected in projected slide pictures with a Gossen´s Lunasix 3 lighting meter.

2.2.2. Physiological recording

Skin conductance (SC), heart rate (HR), finger pulse amplitude (FPA), blood volume (BV), respiration and three EMGs were recorded continuously using a Beckman Type R411 Dynograph. All data signals and stimulus information were recorded on paper. The first three variables with stimulus and trigger pulses were stored on magnetic tape using a Hewlett Packard 3960 Instrumentation Recorder. Pupillary activity was measured by filming the left eye with a Nalcom TTL 2000 Super-8 camera. Electromyographic (EMG) signals were preamplified by Tektronix 26A2 Differential Amplifiers before input to Beckman Type 9852A EMG integrator couplers. Skin conductance measurement was accomplished with a Lykken-type Beckman´s coupler (Type 9844), heart rate with a Type 9857 coupler (cardiotachometer), pulse amplitude and blood volume using Type 9853A general-purpose couplers and respiration via a termistor probe, output of which was fed directly to a preamplifier of the Beckman Dynograph.

In the measurement of EMGs, skin conductance and heart rate standard Beckman Ag-AgCl Biopotential skin electrodes with a surface area of .64 square cm were used. Skin conductance electrodes were placed on the thenar and ulnar hypothenar areas of the palm of the nonpreferred hand and attached, as are all other skin electrodes, with adhesive collars (supplied by Beckman). An electrolyte recipe of Edelberg (1967) was used in preparing the contact media for skin conductance recording. For other electrodes standard Beckman Electrode Paste was used. Heart rate was measured with chest configuration and EMGs from frontal muscles 3 cm above the eyes, forearm flexor muscles 10 cm from the elbow to the direction of the dorsal side of the hand and from orbicularis oris muscles between the mouth and the lower side of the chin. Pulse amplitude and blood volume were measured using the photoelectric transducer by Gilson (Medical Electronics, Inc., type FP-6) from the middle finger of the non-preferred hand. Respiration was measured from the nose with a termistor probe.

Electrode areas were cleaned with Isopropanol and in the case of EMGs the skin was abraded before fixing the electrodes to get a between-electrode resistance lower than 6 Kohm.

The filming of the pupillary diameter was realized from a distance of about 80 cm with a close-up lens placed in front of a zoom lens used at the setting of 60 mm. The eye was lighted with a 1.5 V penlight bulb from an angle which neither disturbed the subject (ie. was not sensible to him) nor constricted the pupil from the level determined by the general lighting, which was 55 lux (as measured with an AEGs UM light meter). Kodak Ektachrome Super-8 film was used. Pupil diameter was quantified using a special projector constructed for viewing single picture frames from motion picture film.

Motor responses were received via a hand-dynamometer. Reaction times were measured with a TS4-33 Electronic Counting and Frequency Meter. The digitization and partial reduction of the analog data were performed with a Hewlett Packard 2110C laboratory computer. Further data reduction and statistical analyses were run mainly with Univac 1100/60 computer in the Computer Center of the University of Jyväskylä.

To minimize problems following from the selection of novice Ss unexperienced with psychophysiological laboratory setting, subjects for the present study were recruited from a population of young males accustomed to electrical instrumentation in their daily school experience (students of electrical instrumentation). This made possible a quite complex ´wiring´ of the subjects with electrical pickups without affecting too much tonic physiological levels. This was found eg. in their heart rate levels which did not exceed normal range (the mean of pre-S2 HR was 73 bpm).

After arriving at the laboratory the subject had time to become accustomed to the laboratory environment, eg. to the masking white noise (of 60 dB).* During this time they were briefly told the general features of the experiment and they could have a look at the instrumentation. After that they were introduced to the subject room for fixing of electrodes. The total time spent in the laboratory before starting the recording was about fifty minutes and the skin electrodes were fixed at least thirty minutes before the first trial of the experiment. Detailed instructions were read after the subject was seated in the laboratory chair comfortably. Following this was a practice phase during which one experimenter checked the physiological signals and another taught the subject the tasks. Each trial type was run twice after its verbal description and subjects had to perform the tasks as required in the experiment. All performance errors were corrected and the trial repeated in the case of erroneous behavior during this phase.

2.3.1. Stimulus contingencies

A two-stimulus paradigm was used, in which two main types of stimuli/events, S1 and S2 were used in paired (within a trial) or unpaired fashion. There were six types of S2-events which were significant to the subject in the sense that S2 was either an unconditioned stimulus or presupposed active (sensory, cognitive or motor) performance from the subject. The main independent variable, information given in advance about significant events, was formed by dividing the Ss randomly into four experimental groups. In three groups the S1 and S2 were paired. The first stimuli (S1) informed about the time and/or content of temporally contingent second stimuli (S2) which were the same for all the groups (except for an additional control group of 6 subjects

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*Noise from an external speaker; dB (A) measured outside headphones.

which experienced only the informative first stimuli). In the fourth main group the two stimulus types were given in unpaired fashion. In this group each trial consisted thus of one S1 or S2 event only, but the total amount of events was, however, equal to that of the other groups.

In the first group, which is here called Noninformed group (NI), the first stimulus was always the same blank slide, which preceded the second by a fixed temporal delay, the interstimulus interval (ISI). Thus the only information given in advance concerned the 'warning' that one of the possible S2s will appear after the fixed ISI period. The ISI was the same in all the three paired groups. The two more informed groups received in the S1 contentual information about the second event. The first stimulus of one of the informed groups included a clue about the second stimulus. They had to decide (or in fact to decipher) which will be the S2. This group is called Partially Informed group (PI). The third group was informed in the first stimulus about the S2 with an explicit label (name) of the S2-event. This group is called Fully Informed group (FI). The fourth group - which experienced unpaired S1s and S2s - was divided into three subgroups each of which experienced one of the three S1-types used in the other three main experimental groups. The group is called Sensitization group (SE) - following the nomenclature used in conditioning literature for describing similar control group.

2.3.2. Stimuli and tasks

The main stimuli were presented visually in slides, but a tone (of 70 dB intensity and 400 Hz frequency) accompanied the S1 presentation. In NI-group all S1s were similar, gray rectangles of 40 x 60 cm having a blank, smaller and lighter rectangle of 4.3 x 24 cm in the middle of the first. In FI-group the smaller rectangle included the name of the significant event. The meanings of the labels were learned during the practise period. In PI-group the information about the S2 was received via deciphering a code which consisted of the letters of the label ordered randomly. This procedure was used to prevent immediate, automated perception of the event and to make necessary a self-realized decision about it.

There were six types of second stimuli (S2). These constituted the critical events and were the same in all the main groups. Trials with these six types of S2 were given in semirandom order as described in detail below. Two of the S2s were UCS-type stimuli, a loud tone (of 87 dB and of 310 Hz frequency; abbreviated below as tS) and a shock (sS). The intensity of the shock was

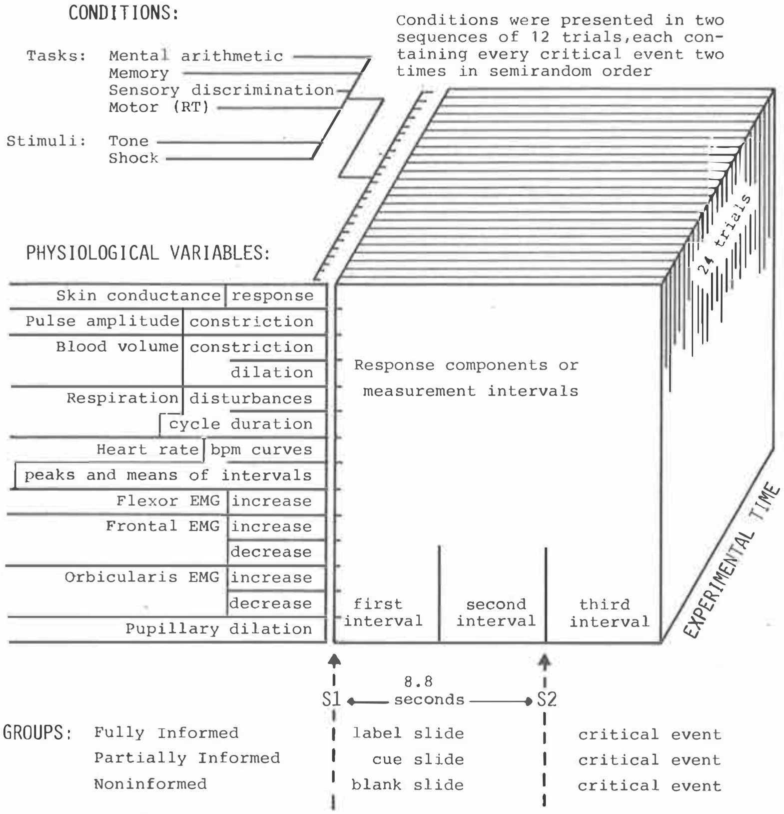

Illustration 1. The main structure of conditions, trials and measures used for each subject in the ´paired´ groups. In Sensitization group S1- and S2-events were presented in unpaired order. (The temporal features of trial axis are simplified in the illustration, see text for details.)

determined according to the tolerance of the subject before the start of the experiment. Each subject was given shocks of increasing intensity and asked to inform which level was ´maximum tolerable´. This level was then maintained by controlling the resistance between electrodes and changing the current accordingly. At the offset of the S1-slide the word ´tone´ or ´shock´ appeared from the second slide accompanying respective, real stimuli. The real UC-stimuli lasted only 1 second but the S2-slide was visible for four seconds. The four other S2s included active participation of the subject in that these offered tasks for performance. These were sensory, cognitive and motor tasks.

In Sensory (Se) task Ss had to decide which of the three lines drawn at different positions in the slide (and labelled A, B, and C) was the longest. Mental Arithmetic (Ar) and Memory (Me) tasks represented purely cognitive tasks. Arithmetic problems included addition, substraction, multiplication and/or division-tasks. The Memory tasks required recall of 5-digit numbers. Subjects had to give the answers to the above three task types after the command given by the experimenter through the intercom. Commands were given four seconds after the offset of the second (ie.task-) slide. The fourth task was a sensomotor (Mo) reaction time task. After receiving in the S2-slide a command ′press now′ the subject had to squeeze as soon as possible the hand-dynamometer he had in the palm of his preferred hand. The pressure needed for closing the contact (to stop the timer) was 10 kg. The main structure of the experimental variables, events and measures is summarized in Illustration 1.

The order of the presentation of the six trial types (conditions) was randomized within cycles of twelve subsequent trials. During such a sequence each of the six trial types was presented two times. Three different randomization orders were made and each of them was given to one third of each group. Two different random sequences of 12 (or 24) trials each were presented subsequently to subject of paired (unpaired) groups to get 24 (48) trials consisting thus of four repetitions of each trial or S2-type. Extensive analyses of variance did not reveal any significant difference between the order groups.

S1 always lasted 8.8 seconds, which was also the ISI, because the slide containing the significant event (S2) was uncovered at the offset of S1. The second slide was projected into the same area as the first 0.8 seconds before its offset. This was necessary for allowing a sufficiently exact timing of the onset of the S2-events technically. The text of the second slide was overshadowed by the lighter rectangle of the first slide so that it could neither be read nor perceived anyway before the offset of the S1-slide. The adequacy of the transparency of each material used in the slides were very critical and were determined empirically with the subjects participating in the preliminary experiments. The Lunasix-determined exposure values (EV) were 12.3 and 9.6 for the bright areas, 8.6 and 7.6 for the background areas, respectively for the S1 and S2 slides. The EVs of the texts were 9.3. When the two slides were overlapping the values were 12.3 for the bright (ie. overshadowed text area), 9.3 for the background and 10.6 for the unovershadowed area including the information of the first stimulus. The content of the S2-slide included the task or name of the stimulus (in the case of tone or shock). The S2-text was visible for 4 seconds.

The inter-trial intervals (ITI) varied randomly between 15 and 40 sec. The range of the ITI was reduced to 12-25 seconds in the SE-group, (in which a single event (S1 or S2) constituted a trial,) to allow an equal number of the critical events (S2) within about the same total time as in the other groups.

2.4. Data reduction

2.4.1. General features

Two main types of scores - phasic and tonic - were derived from the physiological data. Phasic scores consisted of changes appearing within specified intervals during the trials. Tonic scores represented maximum levels of activity during the S1 and/or S2. In the case of heart rate (HR) and skin conductance (SC) scores represented absolute measures of beats per minute (bpm) and micro-ohms (μmhos) respectively. Pupillary diameter changes were quantified in absolute millimeter-scale. The scoring of the other physiological variables was made using arbitrary units and differential scores from the pretrial baseline, because of the lack of a commonly accepted calibration procedure, as is the case with the integrated EMG, finger pulse amplitude, blood volume and respiration. Both phasic and tonic scores were derived from electrodermal, heart rate, pulse volume and pupillary data. Only phasic scores were used when analyzing the data from other physiological variables.

2.4.2. Data reduction procedures

Skin conductance, heart rate and finger pulse amplitude (FPA) were digitized and scored by computer. In the digitization the sampling interval was 40 milliseconds. The programs for digitization and preliminary treating the digitized physiological data are described in detail in Lyytinen & Koskinen (1976), but the main features of the relevant parts of the scoring procedure are described below.

Skin conductance response (SCR) was quantified as the amplitude of change (in μmhos) occurring from a minimum to a maximum with a continuous increase of conductance between these two points. The largest such change starting within a specified interval was taken to represent the skin conductance response (SCR) of this interval. The intervals of interest with respect to SCRs were as follows: 1) first-interval, or S1 response 1.0-5.0 seconds from the onset of S1, 2) second-interval, pre-S2 response 5.0-9.0 seconds from the onset of S1, 3) third-interval response 9.0-13.0 seconds after the onset of S1 or 0.2-4.2 seconds after the onset of the second stimulus and 4) fourth-interval response 13.0-17.0 seconds from the onset of the S1, ie. the four seconds following the S2-offset. (This last measure is reported here only when something interesting or unexpected is found.) In Sensitization group the respective data were derived similarly from the first two intervals following the S1-type of slide. The equivalent scores for the third and fourth intervals were scored with respective intervals from the onset of S2. Two separate scores were quantified from the intervals following S2. The first consisted of 1.0-5.0 seconds from the event-onset and the second consisted of the maximum of the responses found from the two successive four-second intervals from the 1-9 seconds post-S2 period. In this latter case comparison was made with respective combinations of data also in the other groups, ie. by using the larger of the responses found in the third and fourth intervals. Analyses of SCR-data were made after transforming the response scores using the square root of skin conductance change in µmhos+1.

Finger pulse amplitude (FPA) was quantified from the similar first two intervals as SCR and from the third interval which combined the third and fourth intervals of SCR scoring. The FPA responses were determined by using the mean amplitude of the first five peaks following a trigger pulse which preceded by 3.2 seconds the onset of S1 and by calculating the scores as percentage changes from this amplitude to the lowest mean of two consecutive amplitude-peaks found within the specified intervals. The scoring of the data from the Sensitization group followed a similar procedure to that described above in the context of SCR-scoring with one exception: similarly to the scoring of the pre-S2 activity, the baseline data was from the pretrial period of the respective S2 trial.

Other physiological variables were scored manually. In EMGs and respiration five 4.4 seconds' subsequent intervals were separated from the moment preceding by 4.4 seconds the onset of the S1. Durations of the respiratory cycles and deviant forms of them were separately scored. The latter meant scoring of the occurrence of a waveform deviating from the one typical to the preceding intertrial interval, during the specified interval. Similarly the occurrences of a change deviating in amplitude from the range of the pretrial-interval variation were scored separately for changes to the direction of both increase and decrease of integrated EMG-level of frontal and orbicularis oris EMGs. Only increases were scored in the case of flexor EMG.

In subsequent usage of the thus far described physiological variables, the immediate response to S1 onset appearing as the first response is called first-interval response, the pre-S2 response occurring during the second specified interval is called second-interval response and changes following the S2, third- or fourth-interval responses, respectively, always according to the variable-specific details of the time window given above.

The digitized cardiotachometric HR-data was reduced before storing to one tenth so that each of the new scores represented the mean of values read within 0.4 seconds. Such scores were stored from the trigger pulse for 20.8 seconds thus quantifying each trial with 52 bpm scores. Both absolute beat per minute (bpm) scores and bpm change-scores from the mean of the HR-level preceding within 3.2 seconds the onset of S1 were used in the statistical analyses. The typical waveform of increase-decrease-increase was divided into three corresponding separate change intervals and scores were then derived from each of them separately by using either the peak- or mean-values of bpms of each interval. The peak values of the three subsequent components consisted of the maximal accelerative peak (HRp1) occurring within 1-5 seconds from the onset of S1, maximal decelerative change (HRp2) within 5-9 seconds from the onset of S1 and maximal (second) accelerative peak (HRp3) during 1-5 seconds after the S2-onset. Each was scored as a difference of the respective peak-value from the mean pre-S1 level of the trial. The mean scores (HRm1-3) were based on respective mean bpm values of the same time-windows.

Blood volume (BV) was quantified for eight seconds´ S1- (1.0-9.0 sec.) and post-S2 (9.0-17.0 sec.) -intervals, respectively, for constriction (decrease) and dilation (increase) separately. Analyses were made with data expressed as a percentage from the maximal BV-constriction or dilation response found from the subject during the experiment.

The diameter changes of the pupil were quantified manually from the projected film frames and using 1.8 seconds´ sampling interval and representing a trial with eleven post-S1 onset scores. Scores were then formed by calculating percentage-changes from the mean pretrial level of the first three sample-values following the trigger pulse (preceding S1 by 3.2 seconds).

2.5. Subjective data and performance scores

2.5.1. Subjective data

Immediately after the end of the recording session each subject was interviewed about subjective experiences. The subjective rating-data to be reported here was based on post-experimental questionnaire and concerned a) the difficulty and b) the unpleasantness of the tasks/events as experienced during the experiment. The subjects were asked to specify and order the three most unpleasant and the three most difficult conditions. The three most unpleasant and difficult conditions were given scores 3, 2 and 1, respectively, for positions of 1., 2. and 3., others were given 0-scores.

2.5.2. Performance scores

Each performance of the cognitive and sensory tasks were scored as right or wrong and sum scores over them were calculated within task types. Reaction times (RT) were quantified to the nearest millisecond. Scores were measured separately for the initiation of the response (=RT) and for the moment at which the needed ten-kilogram pressure was achieved (PT). The subjective and performance data were not systematically analysed in the present report but are described using correlations for interpretational purposes.

2.6. Statistical analyses

Analysis of variance (ANOVA) and multivariate (principal component, and discriminant) analyses were the basic statistical methods used to describe the results. The main factors in the analysis of variance were information about stimulus contingencies (2-4 between-Ss levels), conditions (ie. S2-types; 2-6 within-Ss levels) and repetition of trials or blocks of trials (1-4 within-Ss levels). In the case of the study of the effect of trial repetition the measuring intervals were also included as a factor in ANOVA. Trend analyses were performed when needed for checking the monotony of the trial effect. When analyzing heart rate and pupillary dilation the response curve was represented with second-by-second score points as ´intervals´-factor in some analyses of variance. The individual interval-scores of the different physiological variables were the dependent variables in the univariate analyses.

ANOVA-factors included repeated measures and statistical homogeneity assumptions were not always met. Thus when needed either conservative (ie. df dropped to its minimum) or the Box-Geisser-Greenhouse Epsilon index also called the Lambda hat index (which reduces dfs in proportion to the violation of the assumptions), were used. Because of complex calculations Lambda hat correction was not always computed in the three-way analyses if significance was achieved already with conservative (ie. minimal) degrees of freedom. In the two-way analyses Epsilon correction was, however, customarily used. Calculations were run mostly using the program package described and offered by Games (1975).

Examination of the patterning of the physiological variables was made by using multivariate analyses. Variables were transformed to comparable units by calculating z-scores over groups and conditions for each (first-, second- and third-interval) component and variable separately. Principal component analyses were computed for describing general patterning of the physiological activity. Stepwise discrimination analyses (SWDA) were performed to find out what features in the response patterns of different measuring intervals best discriminated a) the differentially informed groups b) the conditions and c) the two pre-event intervals as media able to contrast conditions. SWDA was applied using the model introduced by Donchin (1969; Donchin, Kubovy, Kutas, Johnson & Herving, 1973) and Walter & Porges (1976) into analysis of physiological response patterns. Multivariate analyses were computed using SPSS.

3. RESULTS

First each physiological variable is examined separately using 2-4-way (univariate) analyses of variance with trials (or blocks of trials), information, conditions and for some purposes also intervals as the independent variables. The patterning of the physiological changes as a function of the experimental variables is then analysed with multivariate methods.

3.1. Univariate results: Experimental effects on the single variables

Tonic changes are evaluated first for background. In this context the change of the level of activity in skin conductance, pulse amplitude and heart rate over the experiment is described. Thereafter the phasic responses are examined separately for each variable and interval. Scores are blocked over trials before further analyses when possible without losing information. The ANOVA-tables and Newman-Keuls post-hoc test results concerning experimental effects on phasic responses are given in Appendix 2. The abbreviations used to label groups, variables and conditions are summarized in Appendix 1.

3.1.1. Skin conductance

3.1.1.1. Skin conductance level

Changes of tonic skin conductance during the experiment were examined by comparing the absolute conductance-scores (μmhos) across the subsequent trials. Each trial was represented by the maximum conductance achieved during the S1 and S2.

The SC-level decreased as a function of trial repetition both during S1 (F=7.180, conservative (=cons) df 1,76, p <.001) and S2 (F=18.219, cons df 1,76, p <.001) intervals. Both followed a linear trend. Ps of the linear component in the condition-specific analyses achieved significance in all conditions with only one exception. The S1-level of Motor condition (Mo)

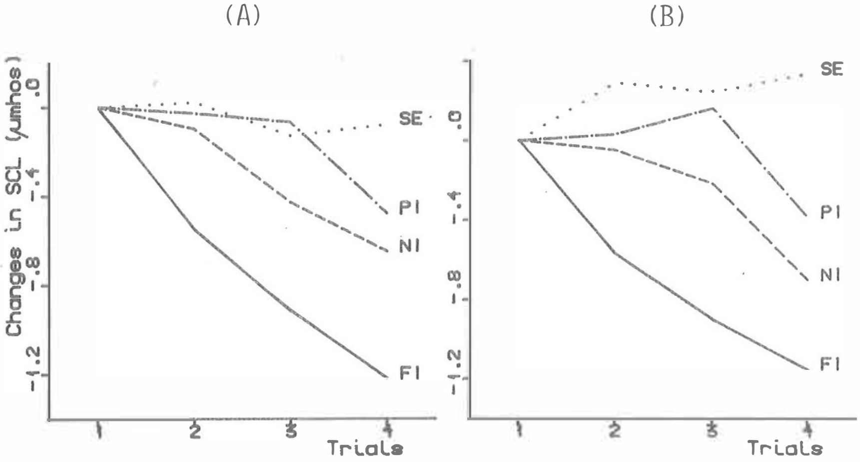

Figure 1. Changes in skin conductance level during S1-interval in the differentially informed groups as a function of trials in the (A) shock-Stimulus and (B) Mental Arithmetic conditions.

failed singly to disclose trial-related change (F=2.156, cons df 1,76, p <.15), but no significant interaction between conditions and trials emerged when all conditions were in the analysis. Groups, however, differed in this linear trial effect in two conditions, viz. in the shock-Stimulus (sS; F=3.580 df 3,76, p <.022) and Arithmetic (Ar; F=5.890 df 3,76, p <.002) conditions in S1-level. The falling trend characterizing the trial repetition did not appear in Sensitization (SE) group, as presented in Figure 1.

Information did not produce any significant simple main effect in the data of either S1- or S2-levels. The S2- activity was very significantly condition-specific (F=16.567, Lambda hat corrected (=Lh) df 3,262, p <.000). S2-levels were higher in Motor (Mo) and shock-Stimulus (sS) than in the other conditions and this appeared in all groups without interactions.

3.1.1.2. Skin conductance responses

Trial effects. The simple main effect of trials was significant (F=35.133, cons df 1,76, p <.000), but the trials factor interacted with intervals (F=5.606, cons df 1,76, p <.02). A trials x intervals interaction (F=7.537, df 1,76, p <.008) in the linear trend was found and it seemed to be due to component-related difference in reduction of SCR-amplitudes as a function of trials. In the interval-specific ANOVAs the immediate responses to S1 and S2 onsets (ie. the first and third-interval responses) displayed significant decrease (Fs for the first interval=20.431, cons df 1,76, p <.000 and for the third-interval=19.807, cons df 1,76, p <.000) but the second-interval response did not (F=1.825). Both the first- and third-interval changes over trials followed a linear trend without interactions with the other factors.

Because the trial-effects within each response interval were monotonic and demonstrated no interaction with the main experimental variables (information or condition) trials were blocked before further component-specific analyses.

Experimental effects. The **first-interval** response displayed a very significant condition-effect (F=4.196, Lh df 4,277, p <.003) which tended to be specific to the information given in S1. The interaction between groups and conditions approached significance (F=1.784, Lh df 4,277, p <.057). Figure 2A and the mean comparison test demonstrate that the Fully Informed (FI-) group responded to S1 with more specificity than the other groups. The Newman-Keuls procedure established that the Motor task (t-values of difference to other conditions in FI ranging from 3.5 to 5.1 when their critical value for p <.05 was 3.1) and shock-Stimulus condition (t-values from 3.3 to 4.3) were anticipated with higher SCRs than the other conditions in FI-group, but not in the others. The overall mean of sS-condition was higher than that of the other conditions, but the difference attained statistical significance only with relation to Ar-condition.

The **second-interval** responses revealed a clear condition-specific pattern (F=3.451, Lh df 4,315, p <.009), which was affected by information (interaction F=2.526, Lh df 12,315, p <.004). The mean comparison tests disclosed that Motor and cognitive tasks were preceded by larger responses than the tone-Stimulus (tS) and Sensory conditions (Se) in Fully Informed group. Also in Partially Informed group some specificity could be observed; thus Motor condition was preceded by larger SCRs than Sensory task-condition. Before the imperative signal for the motor response the two informed groups (FI and PI) responded with significantly larger pre-S2 SCRs than did Sensitization group during the comparable S1-interval interval. See Figure 2B.

The **third-interval** response (ie. the immediate response to S2) revealed both a very pronounced condition effect (F=33.466, Lh df 3,262, p <.000) and also a significant interaction between groups and conditions (F=5.051, Lh df 10,262, p <.000). Pairwise comparison tests verified that both Noninformed

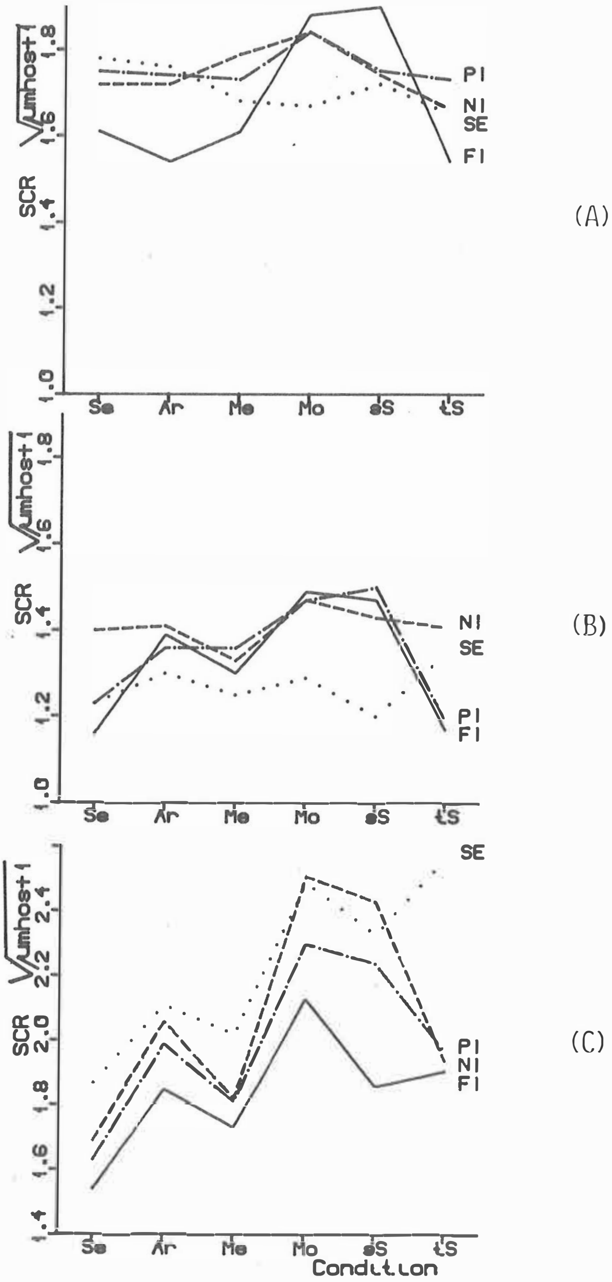

Figure 2. Mean skin conductance responses during the (A) first, (B) second and (C) third interval in the differentially informed groups.

and Sensitization groups responded with higher amplitudes than the other groups in sS-condition and the Sensitization group also in tS-condition. See Figure 2C. The mean responsivity of the informed groups (PI and FI) were in most conditions lower than that of the other groups but also in these first groups Stimulus conditions (ie. tS and sS) and Motor task tended to be accompanied by higher, and Sensory task by lower responses than in the other conditions. In Noninformed group the pattern of SCRs was quite specific (Mo, sS >others; Ar, Me >Se). The corresponding pattern was quite similar (Mo, sS, tS >others) in Sensitization group. In Fully Informed group the SCR-profile across conditions was flatter than in the less informed groups.

3.1.2. Pulse amplitude

3.1.2.1. Pulse amplitude level

The FPA-level changed significantly during the experiment (F=6.802 cons df 1,76, p <.012), with a significant linear trend in Sensory, Memory, Motor and sS-conditions. It appeared as an increase of the absolute pulse amplitude in all but Sensitization group, which did not exhibit habituation as presented in Figure 3 (interaction F=2.836, cons df 3,76, p <.044).

The FPA-levels of the S1-interval did not display any effect of information or conditions. The S2 FPA-levels were specific to conditions (F=15.739, Lh df 4,287, p <.000). The mean comparison established that the order of significantly (p <.05) different levels were from more to less constriction as follows: Arithmetic >other conditions, except Memory and Motor tasks which were accompanied by lower amplitude levels that Sensory and Stimulus-conditions. The groups did not differ in this comparison.

3.1.2.2. Pulse amplitude responses

Trial effects. Only the first, immediate response to S1 exhibited consistent decrease (habituation) in constriction as a function of trials. Component-specificity in the habituation was verified by the significant interaction effect of trials and intervals (F=3.744, standard df 6,456 and cons df 1,76 give ps of <.001 and <.057, respectively, and because the violation of homogeneity assumptions was not maximal (Epsilon >.3) as supposed in the conservative solution, the difference is significant at least on the 2.5 percent level).

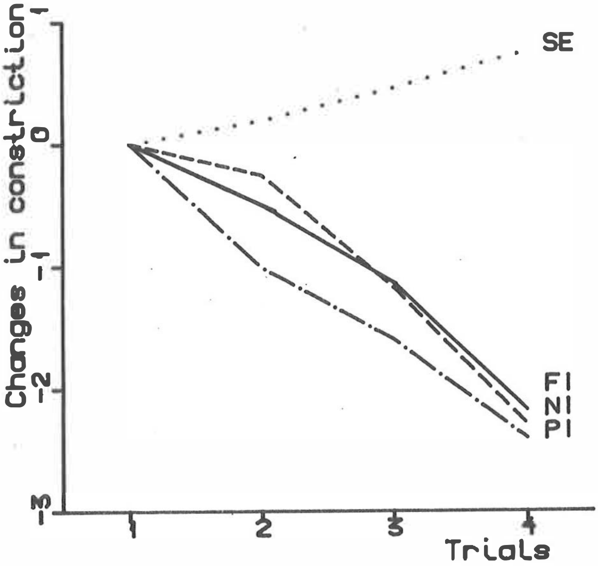

Figure 3. Changes in finger pulse amplitude levels during S1-interval in the differentially informed groups.

Also the second component had a significant trials main effect, but in this case also the groups x trials interaction achieved significance (F=3.701, cons df 3,76, p <.015). It resulted from a pronounced dilative trend appearing in Noninformed group whose responses to the first trials were very constrictive. The other groups did not exhibit a significant trial effect during the second interval.

Because of somewhat ambiguous trial effects further analyses were made using blocks of 1-, 2-, and 4-trials.

Experimental effects. The **first-interval** component of FPA revealed no significant information-related effect. The conditions elicited consistent and similar constrictions within and between groups. These results were independent on blocking of the data over trials.

The analysis of the **second-interval** component of FPA was complicated by a small difference depending on the blocking of trials. The first trials were accompanied by more constriction in the Noninformed group as shown above, but this difference between groups dissipated during the last two trials. A quite consistent picture emerged from the analysis of data blocked over the four trials. The Sensitization groups displayed less constriction than the others, except for Partially Informed group (F=5.780, df 3,76,

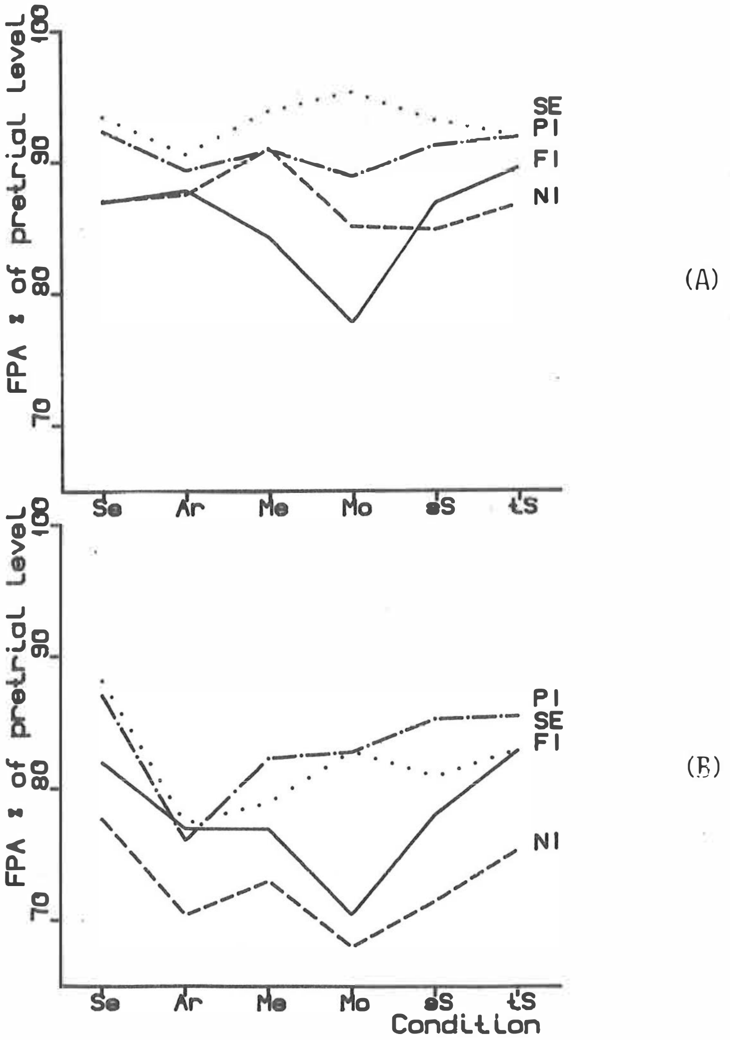

Figure 4. Finger pulse amplitude-changes as mean percentages from the prestimulus level during the (A) second and (B) third interval in the differentially informed groups.

p <.001). The interaction of groups with conditions was also significant (F=2.594, Lh df 13,336, p <.002). Mean comparisons confirmed that in Motor condition Sensitization group responded with lesser constriction than any other group and in the other conditions it differed only from Fully Informed group. The groups which had no or only partial advance information about conditions responded with similar constrictions during all conditions, while Fully Informed group exhibited S2-specific responses, as presented in Figure

4A.

The **third-interval** component of FPA was reliably affected by information (F=4.446, df 3,76, p <.006). Noninformed group had more constrictions than the others excepting Fully Informed group. Also conditions had a significant main effect (F=16.033, Lh df 4,315, p <.000) resulting from more constrictive FPAs during the cognitive (Ar, Me) and Motor conditions than during the others. These two factors showed also a significant interaction (F=2.248, Lh df 12,315, p <.010), which was shown by the Newman-Keuls mean comparison (see also Figure 4B) to result from several reasons. One of them was the more pronounced constriction in Noninformed group compared to other groups in Mental Arithmetic condition. Partially Informed group displayed less constriction than NI- and FI-groups in sS- and Motor conditions. In Motor condition the means of these last two groups also showed more constriction than did the Sensitization group. In Partially Informed group Mental Arithmetic task and in Fully Informed group Motor condition produced larger constrictions than all the other conditions.

3.1.3. Heart rate

The beat per minute (bpm) means of eight-second S1- and S2-intervals of each trial were examined as the data of tonic HR-variation. The scores of phasic HR consisted of the beat-by-beat changes, and peak and mean changes of each specified interval from the pretrial level.

3.1.3.1. Tonic heart rate

Heart rate level declined over trials monotonically (S1:F=42.033; S2:F=65.188, cons df 1,76, ps<.000) without interactions with groups or conditions both in S1- and S2-interval measures. For further analyses trials were blocked.

Heart rate level did not vary significantly as a function of information during the S1-interval. But the conditions were accompanied by different mean HR-levels (F=5.775, Lh df 4,337, p <.000). These condition-specific HR-levels did not, however, appear in all groups, the groups x conditions interaction was significant (F=3.210 Lh df 13,337, p <.000). Follow-up analyses revealed that in Fully Informed-group the S1-levels varied as a reliable function of conditions as follows: sS, tS <others. The other groups did not display differential HR-levels across conditions.

HR-level showed significant main effects of both groups and conditions during the S2-interval (F=65.053, Lh df 4,329, p <.000) but there was also a significant interaction between them (F=2.465, Lh df 13,329, p <.003). The between-condition comparison displayed the following pattern: Mental Arithmetic >Motor and Memory task >Sensory task >sS, tS. Partially Informed group had higher mean HR than Noninformed group. All groups had similar general profiles across conditions with 4-6 bpm lower levels during the tone and shock-Stimuli to those during the cognitive tasks. In Motor task, however, Noninformed group achieved a relatively higher level than the other groups.

3.1.3.2. Phasic heart rate

The general pattern of the mean bpm-curve followed a consistent general course (the main effects of interbeat-intervals were very significant (p <.000). The curve formed a triphasic acceleration-deceleration-acceleration pattern. When such beat-by-beat data are submitted as an (´intervals´-) factor to ANOVA its interactions with the experimental factors reflect the effect of the latter on the phasic heart rate activity.

Trial effects. The first and the third but not the second (ie. the decelerative) component of this triphasic cycle seemed to be affected by the trial repetition. None of the related simple main effects of trials achieved significance, but the three-way interaction groups x conditions x trials was significant in tests conducted on the first mean (of 1-4 sec.) change (from baselevel, ie. HRm1-) data (F=1.815, Lh df 32,814, p <.012). The third component, the acceleration following the S2 onset, showed trial effect both in the peak difference between the four-second pretrial mean-bpm and the maximum HR reached during the first four S2-seconds and in the mean-bpm difference from the same prestimulus baselevel. In the latter it was most pronounced (F=9.119, cons df 1,76, p <.003). It had also a significant interaction with conditions (F=3.004, cons df 3,76, p <.036). But also the groups x conditions x trials interaction was significant (F=2.041, Lh df 31,800, p <.001). Accordingly the trials were blocked in the data submitted to analyses concerning the decelerative component of the pre-S2-activity, while both the first and second accelerative components were examined in the subsequent analyses by taking into consideration also the trial effects. The interactions are examined in more detail below.

Experimental effects on the overall form of the heart rate curve. Analyses of the beat-by-beat curves yielded significant interactions of intervals both with information and conditions (information x intervals F=7.117, cons df 3,76, p <.001, conditions x intervals F=15.135, cons df 3,76, p <.000). Additionally the three-way interaction information x conditions x intervals was also significant (F=3.170, cons df 3, 76, p <.05).

As seen in Figures 5A-F these effects followed from several aspects of the HR-variation. The most pronounced difference appeared between Sensitization and the other groups. Both in the S1- and S2-interval data of this group the effect of the experimental variation was less than in the other groups. The S1-related changes were attenuated in this group compared to others especially during the Stimulus-conditions, but also in the cognitive task-conditions. In the Motor task the difference was not significant.

The HR response accompanying S2 was less pronounced in the Sensitization group than in the others, especially during cognitive tasks and in that case also during Motor task. There were also other differences which are more adequately describable in separate analyses given below.

Experimental effects on the phasic HR-changes during S1. To examine in more detail the phasic aspect of HR variation bpm-change scores from the prestimulus level were used in the further analyses. As mentioned, the first consistent change related to the experimental stimulation was HR-acceleration which occurred within 1-4 second from the onset of S1. ANOVAs, performed with data of each condition separately, verified that acceleration was very significant during this period (ranging from F=25.865, cons df 1,76, p <.000 in tS condition to F=42.264, p <.000 in Ar-condition). Trend analyses of this acceleratory change disclosed significant linear trends (Fs from 35.750 to 60.756, with cons dfs of 1,76, p <.000). The Figures 5 A-F, however, illustrate furthermore how both conditions and groups differed from each other and apparently in an interactive way. ANOVAs with the data of 1-4 second **mean change** (HRm1) verified that groups differed from each other significantly (F=5.323, df 3,76, p <.002). The Newman-Keuls test established that Sensitization group differed from all other groups with its lower mean increase of heart rate.

Also the simple main effect of conditions was significant (F=2.911, Lh df 4,338, p <.022) resulting from lower HR-changes during the tone and shock-Stimuli (especially tone-S) than during cognitive conditions. As expected there was a significant interaction between these two factors (F=2.352, Lh df 13,338, p <.005). This resulted from more pronounced condition-specificity

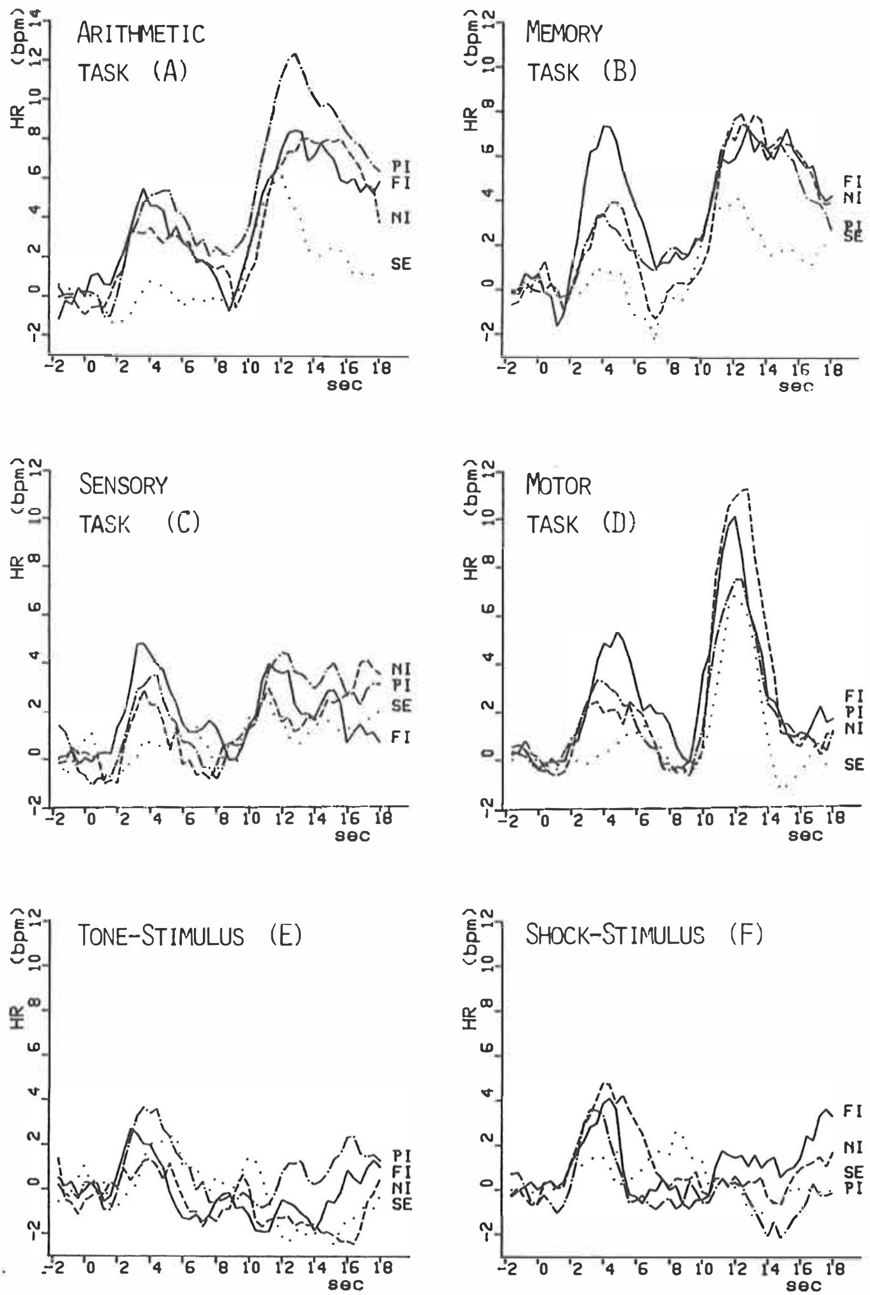

Figure 5. Heart rate curves of the differentially informed groups during (A) Arithmetic, (B) Memory, (C) Sensory, (D) Motor, (E) tone- Stimulus and (F) shock-Stimulus conditions.

characterizing the responses of the two informed groups (FI and PI). In these groups the condition-effect, ie. larger increases preceding cognitive tasks than the sensory stimuli, appeared more clearly than in the other groups. This phenomenon was furthermore complicated by the significant interaction with trials (as mentioned above), which resulted from the fact that in the two more informed groups (FI and PI) the accelerative responses tended to diminish as a function of trials. In Partially Informed group this was most apparent in the cognitive conditions (in which the first trials´ accelerations were highest) and in Fully Informed group, especially in Stimulus (sS and tS) conditions. The Sensitization and Noninformed groups did not display any consistent decrease in any condition as a function of trials.

The **peak-acceleration** (HRp1) score measured from the same 1-4 sec. interval displayed essentially the same results. Sensitization group differed from all others (F=7.336, df 3,76, p <.000). Similarly the information and condition factors interacted significantly (F=2.062, Lh df 14,353, p <.013). Only in the informed groups did the between-condition differences attain significance. These were the same as described above with the mean-HR-change data.

The second component - **deceleration** - was also mainly monotonic in all conditions; linear trend explained most of the variance. (The F´s varied in conditions between 22.26 and 69.13 with cons df of 1/76 and ps <.000). In Sensitization group this linear decrease was less clear as can be seen in Figure 5. The **mean** (HRm2) score attained a significant condition effect (F=3.675, Lh df 4,337, p <.006) which was established in the mean comparison to result from a longer deceleration preceding the tone and shock-Stimuli (especially tS) than the cognitive tasks (especially Ar). The **peak-decrease** (HRp2) score yielded a significant interaction between the experimental factors (F=1.755, Lh df 14,346, p <.044) resulting from the less pronounced decelerations of HR in the informed groups than in the others in the two cognitive conditions. The maximal differences were between Partially Informed and Noninformed groups in Memory and Arithmetic conditions. In Memory task the deceleration also of Fully Informed group showed attenuation as shown in Figure 5.

Experimental effects on the phasic HR-changes during S2. Conditions and trials revealed significant simple main effects. Furthermore these had also significant interactions with information. Cognitive conditions were accompanied by higher accelerations than Stimulus conditions. This difference was highly significant (the main effect of condition F=41.042/61.358, Lh dfs 4,304/309 ps <.003/.001, respectively, for the peak- and mean-scores). Furthermore several of the conditions differed from each other as follows: Arithmetic, Memory and Motor tasks >Sensory discrimination task >Stimulus conditions (sS and tS) in both measures. Sensitization group responded with smaller change-scores, a situation which, however, seemed to occur especially in Cognitive conditions (Ar, Me and Se) as displayed by the significant groups x conditions interaction (F=2.540, Lh df 12,304, p <.003 and F=2.807, Lh df 12,309, p <.001, respectively for the peak- and mean-measures) and by the mean comparison tests.

The interpretation of the information related data was complicated by the significant three-way interaction between information, conditions and trials as mentioned above. This interaction was attributable to a difference in the diminishing trend (habituation?) of HR-acceleration appearing only in the informed groups (FI and PI) in all except Motor condition. The means increased as a function of trials rather than decreased in Noninformed and Sensitization groups especially in sS- and Motor conditions. Thus during the later trials the noninformed (SE and NI) groups responded with higher acceleration than PI in sS- and Motor conditions and SE with larger increases than FI in Stimulus (sS and tS) conditions.

3.1.4. Respiration

Respiratory changes were quantified with two separate phasic scores. These were respiratory cycle duration and respiratory disturbances (nonstandard respiratory cycles).

Trial effects. Trial repetition affected the duration of the respiratory cycle during all intervals. In all cases it became slower as a function of trials (first-interval F=5.716, cons df 1,76, p <.019; second-interval F=6.549, cons df 1,76, p <.013; third-interval F=4.446, cons df 1,76, p <.038). No significant interaction emerged. The trial effect was not significant in the respiratory disturbances. Further analyses were conducted with blocked data.

Experimental effects. The **first-interval** scores of the **nonstandard respiratory responses** uncovered no significant simple main or interaction effect.

The first-interval **duration of the respiratory cycle** did not reveal any simple main effect. There was, however, an apparent tendency in Fully Informed groups to show a conditions-specific response profile as illustrated in Figure 6A. The interaction term verified this difference (F=1.995, Lh df 12,300, p <.024). The mean comparison tests did not, however, yield any significant difference. The most marked mean differences are between the informed and noninformed groups. In Fully Informed group the mean respiratory cycle shortened markedly just before the imperative signal in the Motor condition and tended to be longer during the cognitive conditions.

In the **second-interval** data of the **nonstandard** respiratory responses there was an apparent mean difference between the main groups (NI, SE vs. FI, PI). The ranges of their means were 21-23 vs. 12-15 percent, respectively, but the difference failed to achieve significance (F=2.213, df 3,76, p <.093). The distribution of the disturbances tended also to be related to both information and conditions interactively (the interaction approached significance (F=1.651, Lh df 13,338, p <.070). Unexpectedly Noninformed group seemed to respond with the most pronounced condition-specificity appearing as a heightened probability of respiratory disturbances before the tone and shock-Stimuli and Motor condition. The interaction F failed, however, to achieve significance and thus no conclusion is warranted.

The second-interval data of the **duration** of the respiratory cycle also tended to show a group-difference. Sensitization group responded with the longest and the informed groups (FI and PI) with the shortest cycles. But although the mean differences were quite marked (see Figure 6B) the simple main effect of groups did not attain significance because of high variability in the data of the Sensitization group. Conditions differed significantly (F=7.242, Lh df 4,281, p <.000). Cycle-durations were longer preceding tone- and shock-Stimuli than before Motor and Memory tasks. Figure 6B suggests the possibility that this would result from more marked condition-specificity in the informed groups, but the interaction failed to disclose significance.

The **third-interval** data of the **nonstandard** respiratory cycles revealed a significant simple main effect of information (F=2.786, df 3,76, p <.047) resulting from a stronger tendency of the Sensitization group compared to Fully Informed group to respond with respiratory disturbances. Conditions also differed significantly from each other (F=6.972, Lh df 4,330, p <.000). Motor task and tone-Stimulus conditions exhibited higher means than the cognitive task conditions. As indicated by the significant interaction between groups and conditions (F=2.107, Lh df 13,330, p <.014) it did not, however, appear in all groups. This clear condition-specificity was significantly present only in Noninformed group. It appeared also as a significant mean difference between the informed (FI- and PI-) and less informed (SE- and NI-) groups

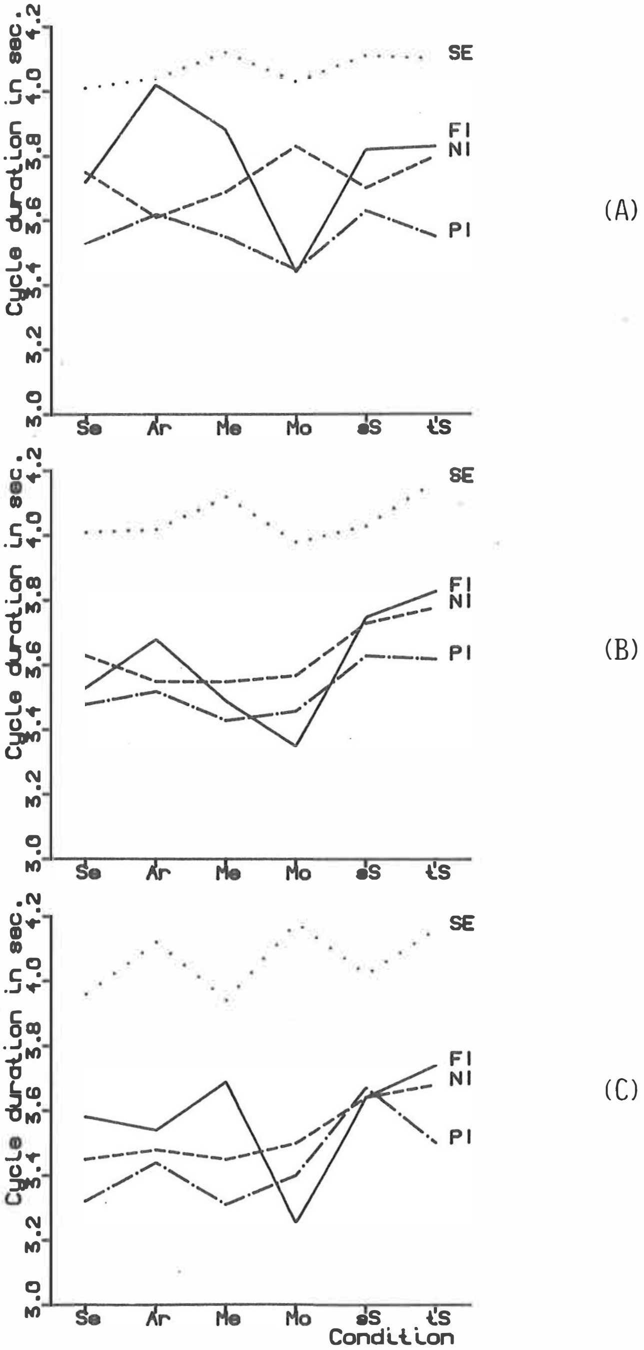

Figure 6. Duration of the respiratory cycle during the (A) first, (B) second and (C) third interval in the differentially informed groups.

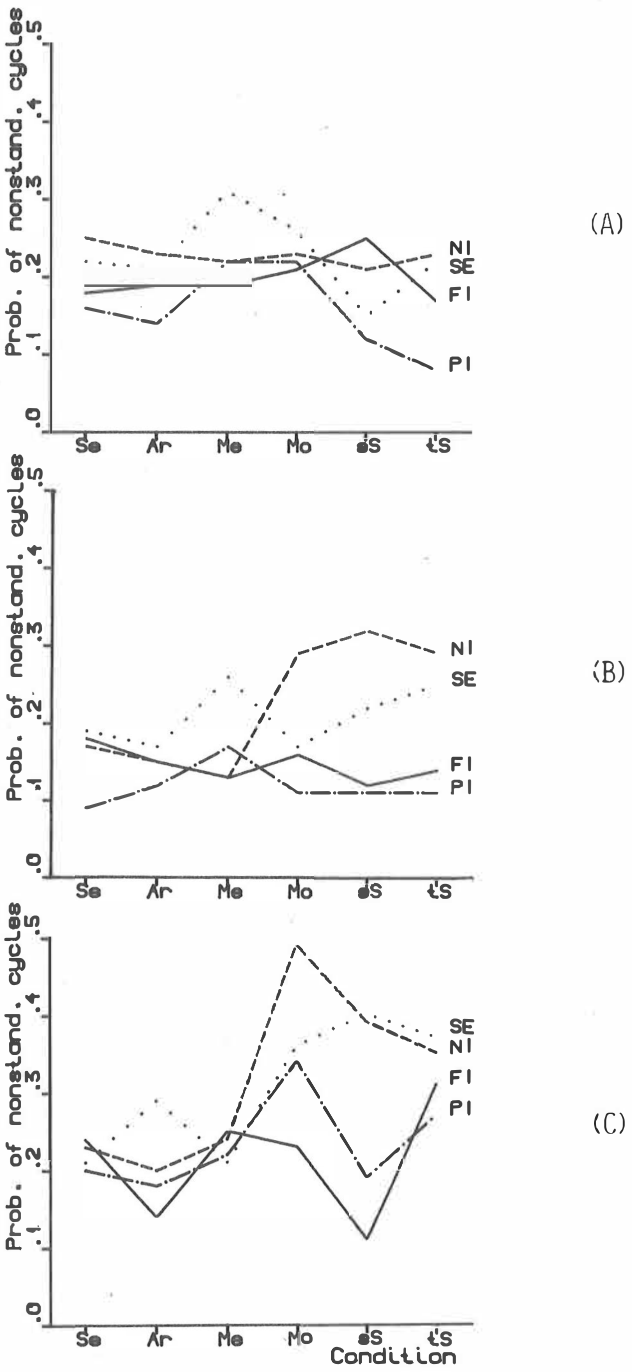

Figure 7. Probability of a nonstandard respiratory response during the (A) first, (B) second and (C) third interval in the differentially informed groups.

in the shock-S condition, in which the former showed less disturbances. In sS-condition 39 percent of respiratory events were nonstandard in form in the Noninformed and 32 in Sensitization group, but only 7.8 percent in Fully Informed group. See Figure 7 C. Motor condition revealed also a significant group difference. In this case, however, it was achieved only between NI- and FI-groups.

The third-interval data of the **duration** of the respiratory cycle revealed differences between conditions (F=4.370 Lh df 4,296, p <.001). The experimental factor showed also interaction (F=2.052, Lh df 12,296, p <.020) which resulted, according to the mean comparison test, from the exceptional tendency of Fully Informed group to respond with longer cycles during the cognitive tasks than during the Motor task. See Figure 6C.

3.1.5. Blood volume

Trial effects. None of the blood volume measures of either S1- or S2-intervals exhibited significant modification as a function of trials. Trials were blocked preceding further analyses.

Experimental effects. During the **first stimulus** (S1) information had no reliable main effect on blood volume **dilation.** The condition effect was, however, significant (F=2.717, Lh df 5,360, p <.020). Mental Arithmetic and Memory conditions were preceded by larger dilations than Sensory task condition. This appeared consistently in the informed groups and not at all in Sensitization group. The group difference was not, however, large enough to result in a significant interaction effect (F=1.392, Lh df 14,360, p <.154).

Blood volume **constriction** did not display any significant main effect during S1. The experimental factors, however, interacted significantly (F=1.870, Lh df 14,360, p <.028) resulting from more pronounced vasoconstriction before Motor task in Fully Informed group. The other differences were not stable enough to achieve a significant t-value in the Newman-Keuls test.

During the **second stimulus** (S2) the groups differed (F=14.405, Lh df 3,76, p <.000) in BV-**dilation** , which was the largest in Sensitization group, and Partially Informed group also had higher means than the last two groups (ie. SE>PI>FI,NI) as established by the Newman-Keuls mean comparisons. The conditions factor showed also a simple main effect (F=7.415, Lh df 4,313, p <.000). Pairwise comparison tests confirmed that it resulted from the condition-specific pattern disclosing significance only in Fully Informed

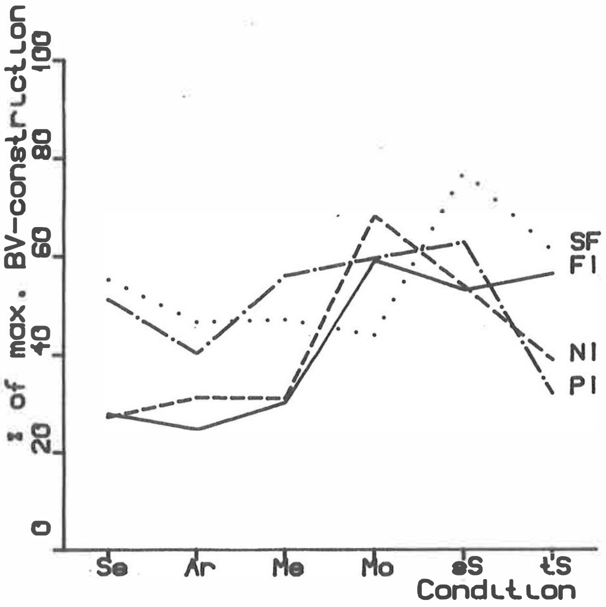

Figure 8. Blood volume constriction during S2 in the differentially informed groups.

group. The stimuli and motor performance tended in this group to elicit significantly less dilation than the cognitive tasks (especially Ar). The overall interaction term did not, however, attain significance because a similar but less pronounced distribution of condition-means tended to characterize the other groups, too.

Also blood volume **constriction** revealed significant main effect of information during S2. Sensitization group was more responsive than the other groups (F=3.586, df 3,76, p <.018). Conditions also produced unequal vasoconstrictions (F=7.449, Lh df 4,342, p <.000) appearing as a larger responsivity during Motor and Stimulus-conditions compared to Cognitive conditions. This tendency was strongest in Noninformed and Fully Informed groups, whose profiles over conditions produced a significant interaction of groups and conditions (F=2.190, Lh df 13,342, p <.010). The shock-Stimulus was accompanied by the largest constrictions in all groups, as displayed in Figure 8.

3.1.6. EMG changes in flexor

Trial effects. EMG in the flexor muscle did not exhibit any significant trial-related effect. The trials were blocked for further analyses.

Experimental effects. During the **first interval** the flexor response probability was significantly affected by information (F=9.684, df 3,76, p <.000). Also the condition-factor displayed a significant main effect (F=5.473, Lh df 5,345, p <.000). Information and condition factors interacted, however, also significantly (F=2.663, Lh df 14,345, p <.001). The activity of the flexor behaved as a positive function of information, being lowest in the Sensitization group and highest in Fully Informed group. The two informed groups differed significantly from the two noninformed groups in the mean comparison test. Motor condition, which evoked larger activity than the other conditions, also made the largest contribution in this group difference. Also in the other conditions (excepting the Sensory task) the informed groups differed significantly from the Sensitization group. In most conditions Fully Informed group differed also from Noninformed group as can be seen in Figure 9A.

During the **second interval** the flexor response probability followed the same pattern as did the first-interval response. The main effects of information and conditions were significant (F=8.771, df 3,76, p <.000 and F=12.647, Lh df 4,337, p <.000, respectively), but also interacted (F=1.777, Lh df 13,337, p <.047) so that the flexor activity was, especially in Motor condition, the larger the more information Ss were given. The informed groups tended to exhibit more activity also during the other conditions as presented in Figure 9B. The mean comparison tests confirmed that Sensitization group responded less in all but Sensory task and tS-conditions. Unexpectedly, also the means of Noninformed groups revealed that probably at least some of the Ss had been able to predict correctly Motor condition as can be seen in Figure 9B.

During the **third interval** the flexor response probability was again significantly different between groups. Sensitization group responded with significantly lesser EMG-activity than the other groups and Partially Informed group more than Noninformed group (F=17.738, df 3,76, p <.000). Condition-factor displayed a highly significant main effect (F=84.263, Lh df 4,292, p <.000). Motor task naturally elicited maximal activity in the responding hand and this accounts for most of the variance differentiating the conditions. As suggested by Figure 9C there was a clear interaction between the experimental factors (F=3.092, Lh df 12,292, p <.000) resulting from lesser

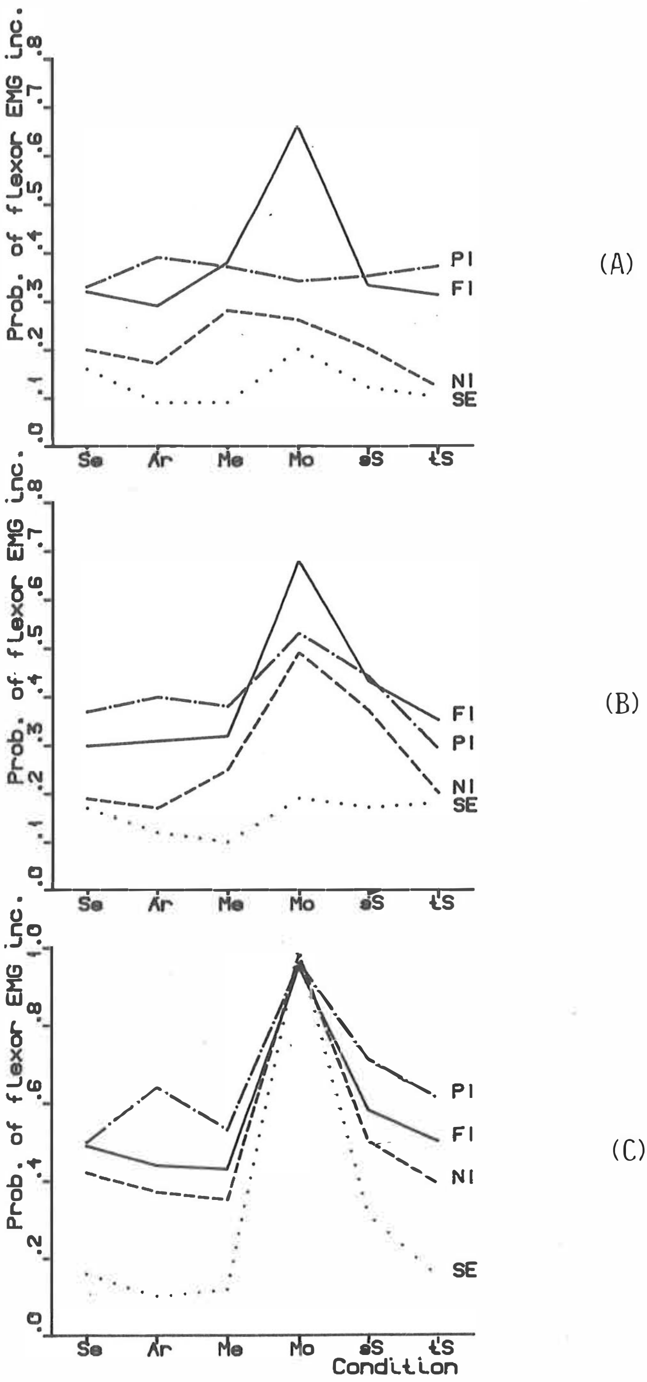

Figure 9. Probability of flexor EMG increase during the (A) first, (B) second and (C) third interval in the differentially informed groups.

EMG-activity in Sensitization group in all others except Motor and shock conditions. Shock-Stimulus elicited significantly larger responses than Ar in the Sensitization group, but otherwise its responsivity to S2s was low and flat across conditions.

3.1.7. EMG changes in frontalis

Trial effects. The frontal EMG did not show any consistent modification as a function of trial repetition. Thus the further analyses were conducted with data blocked over trials.

Experimental effects. During the **first interval** the frontal EMG response probability exhibited one information-related marginally significant difference. It appeared in the main term of information in the EMG-**decrease** from the prestimulus range (F=2.703, df 3,76, p <.051) showing a monotonic relation to the amount of information given in advance. Stimulus conditions (sS, tS) tended to be preceded by a more probable decrease in Fully Informed than in the other groups, but both the related main and interaction effects fell short of significance in the F-test. However, this difference achieved significance in the Newman-Keuls mean comparison test, when comparing groups within conditions. (The obtained t=2.77 was higher than the critical t=2.72 for p <.05 in FI>SE contrast of sS-condition and t=3.11 > 2.72 of tS-condition). The more pronounced condition-specificity in the means of FI-group was apparent as can be seen in Figure 10A. The profile suggests that it has responded with more pronounced EMG-decrease than the other groups especially in Stimulus conditions, while no difference appears in Motor condition.

During the **second interval** the frontal response probability revealed one significant effect. Information had a simple main effect on EMG-**decrease** (F=3.062, df 3,76, p <.033). The mean differences followed monotonically the amount of information available to the groups, as presented in Figure 10B. EMG-**increase** scores did significantly contrast groups or conditions neither during the first nor the second interval.

During the **third interval** the frontal response probability showed several significant effects. Information had a very significant effect on EMG-**decrease** (F=12.757, df 3,76, p <.000). The distribution of means followed the amount of information given in advance. An inspection of the means reveals that the mean of Fully Informed group (0.60) is almost two times that present in Sensitization groups (0.32), while the other means fall between

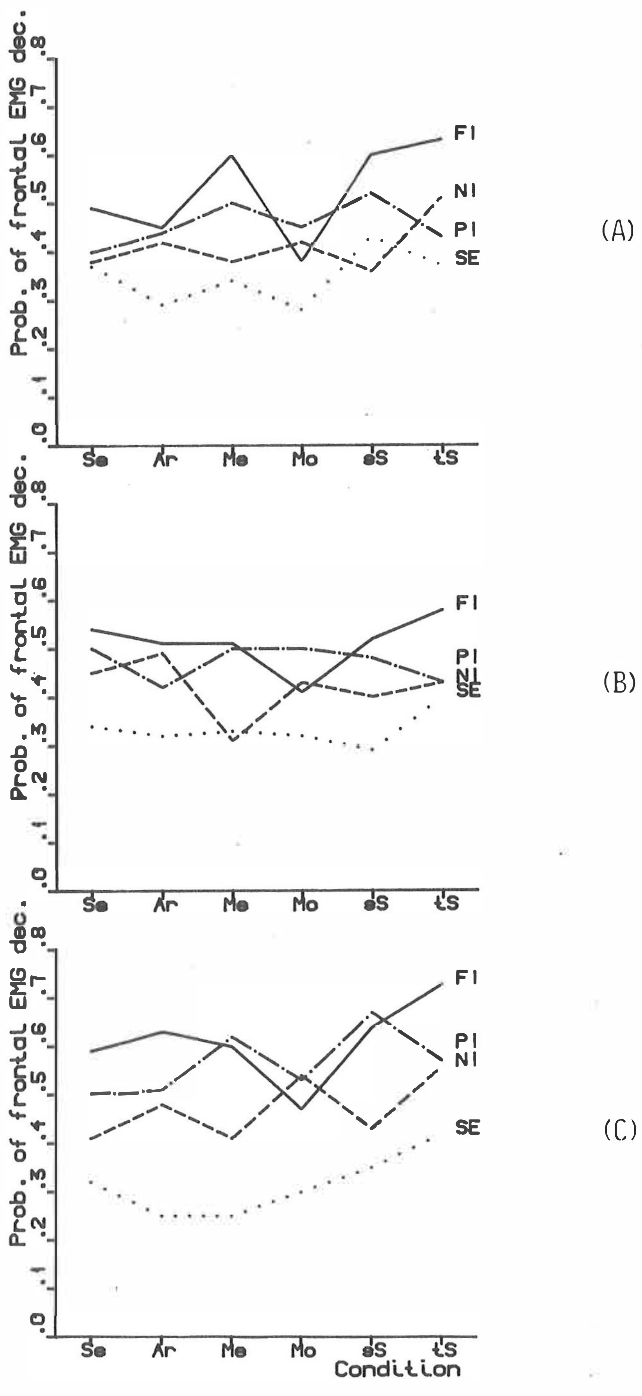

Figure 10. Probability of frontal EMG decrease during the (A) first, (B) second and (C) third interval in the differentially informed groups.

these two. Also the condition main effect was significant (F=2.360, Lh df 5,346, p <.040) resulting mainly from higher probability of decrease as a response to tone-Stimulus than during the motor performance. The interaction term of groups and conditions was nonsignificant, but, however, the mean comparisons showed that Fully Informed group and for the most part also Partially Informed group responded significantly more probably with decrease to S2 (p <.01) than did Sensitization group in all other conditions except Motor condition. In shock-Stimulus condition also NI-group showed less decrease than the two more informed groups.

It is worth noting in this connection that the subsequent four-second-interval after the offset of the S2 continued to show a difference which may be related to the advance information. The informed groups responded with more EMG-decrease than the noninformed groups in two cognitive conditions, although the other conditions no longer revealed any difference. This may result from the effect an advance preparatory information offers for the fluency of performance in such tasks.

No statistically significant F-value was found for EMG-increase. However, the interaction term information x conditions approached it (F=1.642, Lh df 14,367, p <.066) and the Newman-Keuls comparisons established significant difference between Noninformed (>) and Fully Informed group in the shock-Stimulus condition.

3.1.8. EMG changes in orbicularis oris

Trial effects. None of the measures revealed any significant trial effect. Trials were therefore blocked for further analyses.

Experimental effects. During the **first interval** the orbicularis response probability showed several information-related effects. EMG **increase** revealed no significant main effect but showed interaction of groups and conditions (F=1.774, Lh df 14,364, p <.041). In the cognitive tasks the speech-organ EMG increased immediately after the onset of the labelled S1 (ie. in Fully Informed group). Also the Motor task was preceded by a significantly larger increase than the sS-condition in this group. Other groups did not display condition-specificity as presented in Figure 11A.

During the **first interval** the EMG **decrease** contrasted significantly the groups. Partially Informed group responded more often with decrease than any other of the groups as proved by the very significant main effect of

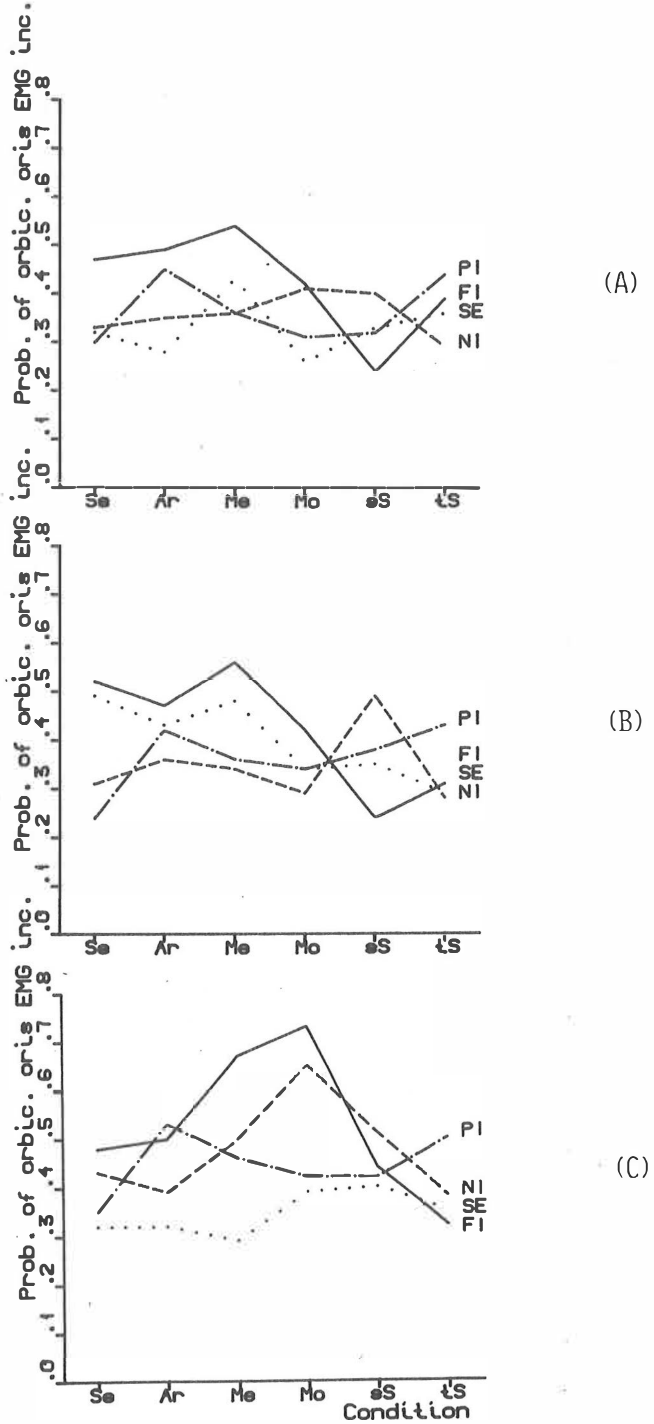

Figure 11. Probability of orbicularis oris EMG increase during the (A) first, (B) second and (C) third interval in the differentially informed groups.

information (F=10.354, df 3,76, p <.000) and Newman-Keuls comparison test (see also Figure 12 A). There was also significant interaction between groups and conditions (F=2.788, Lh df 14,364, p <.001), which resulted from the stronger tendency of the informed groups to indicate condition-specificity. As confirmed by the mean comparison test, Fully Informed group responded significantly more frequently with decrease to stimulus-labels than to cognitive task (Ar,Me) labels. Partially Informed group tended to respond with EMG-decrease significantly more frequently than the other groups in all but the sensory (Sensory task and tS-) conditions, in which the difference was short of significance.

During the **second interval** the orbicularis response probability was also affected by information. In EMG-**increase** the main effect of conditions was significant (2.583, Lh df 14,346, p <. 026), but condition and information factors also interacted (F=2.749, Lh df 14,346, p <.001) and the mean comparison revealed no general mean difference between conditions. The condition-specificity appearing in one group contributed most to the significant F as expected from the profiles illustrated in Figure 11B. In Fully Informed group the cognitive conditions (including Se) were accompanied more probably by a pre-S2 EMG increase than were Stimulus-conditions. There was furthermore one specific difference appearing in Noninformed group. This group responded to sS-condition with marked increase of EMG in orbicularis oris. This was in contrast to the behavior of the Fully Informed group, which showed reduced activity in anticipation of the shock-Stimulus. In those cases the pre-shock EMG means differed significantly not only from each other but also from the means of the other conditions within the groups. No consistent condition-specificity could be detected in the anticipatory EMG-increase in the other groups.

The analysis of the second-interval EMG-**decreases** revealed a significant effect of groups (F=5.394, df 3,76, p <.002) and conditions (F=2.944, Lh df 5,349, p <.013). Partially Informed group showed more decrease than any of the other groups. Cognitive tasks were anticipated with significantly less decrease than tS condition. Although the interaction of information and conditions did not quite achieve significance (F=1.658, Lh df 14,349, p <.065), the pairwise comparison supported the expectation emerging also from Figure 12B that the between-condition differences are evident only in Fully Informed group.

During the **third interval** the orbicularis response probability showed marked group- and also condition-specificity and also interactions between

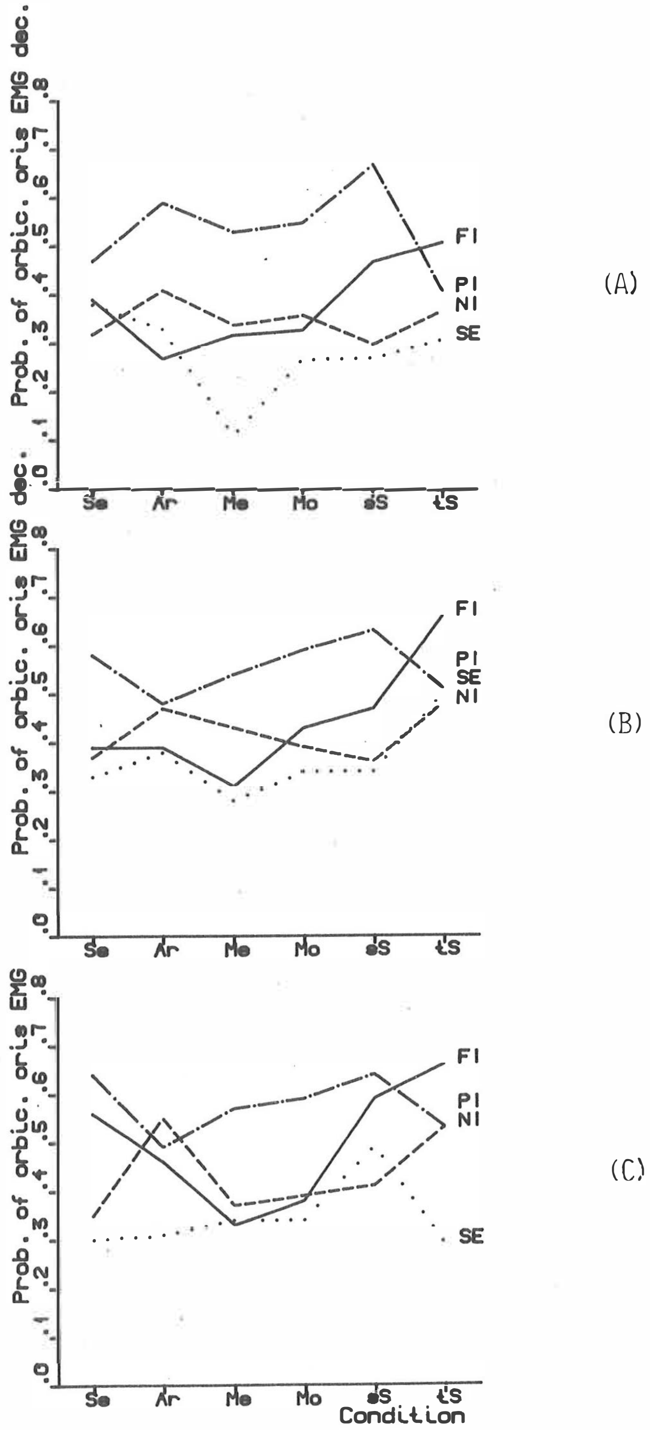

Figure 12. Probability of orbicularis oris EMG decrease during the (A) first, (B) second and (C) third interval in the differentially informed groups.

them. In the EMG-**increase** the means of the groups varied as a positive function of the information given in advance to the Ss (F=5.722, df 3,76, p <.001). Sensitization group displayed less increase than the other groups. The means reveal that Motor condition was accompanied by more activity than Se- and tS-conditions, resulting in a significant main effect of conditions (F=3.727, Lh df 4,333, p <.006). Fully Informed group achieved some further significant contrasts between conditions (interaction F=2.365, Lh df 13,333, p <.005). See Figure 11C. The mean comparison verified that Motor task in this group elicited more activity than the tone and shock-Stimuli and Memory task more than Sensory or Arithmetic tasks. The groups differed clearly in Memory and Motor tasks in which Fully Informed group had a higher probability of exhibiting increased EMG-activity than Sensitization group.

The two least informed groups displayed less **decrease** of EMG than the two informed groups (information F=7.542, df 3,76, p <.000). The activity was unevenly distributed over conditions also. The Stimulus-conditions (especially sS) revealed more decrease than did Motor and cognitive (especially Memory) task conditions (F=2.947, Lh df 5,361, p <.013), and this was especially marked in Fully Informed group as illustrated in Figure 12 C. This was supported also by the significant interaction (F=2.466, Lh df 14,361, p <.003) which, however, resulted from a complex pattern of significant differences. In most conditions (Se,Me,Mo,tS) one or both of the informed groups (FI, PI) responded with significantly larger decreases than one or both of the less informed (NI,SE) groups.

3.1.9. Pupillary activity

Pupillary measures were taken only from 30 subjects, from ten Ss of FI-, PI- and NI-groups each.

Response curve and trial effects. The course of activity proved to be affected by the experimental stimuli as verified by the very significant main effect of intervals (ie. the second-by-second scores F=87.890, cons df 1,27, p <.000). The form of the dilation curve did not change as a function of trial repetition; no significant trial-related effect was found. Trials were therefore blocked before further analyses.

Experimental effects. During S1 the pupillary diameter varied reliably. In all of the three groups and six conditions a clear biphasic change, a constriction from the pretrial level and a subsequent dilation of the pupil,

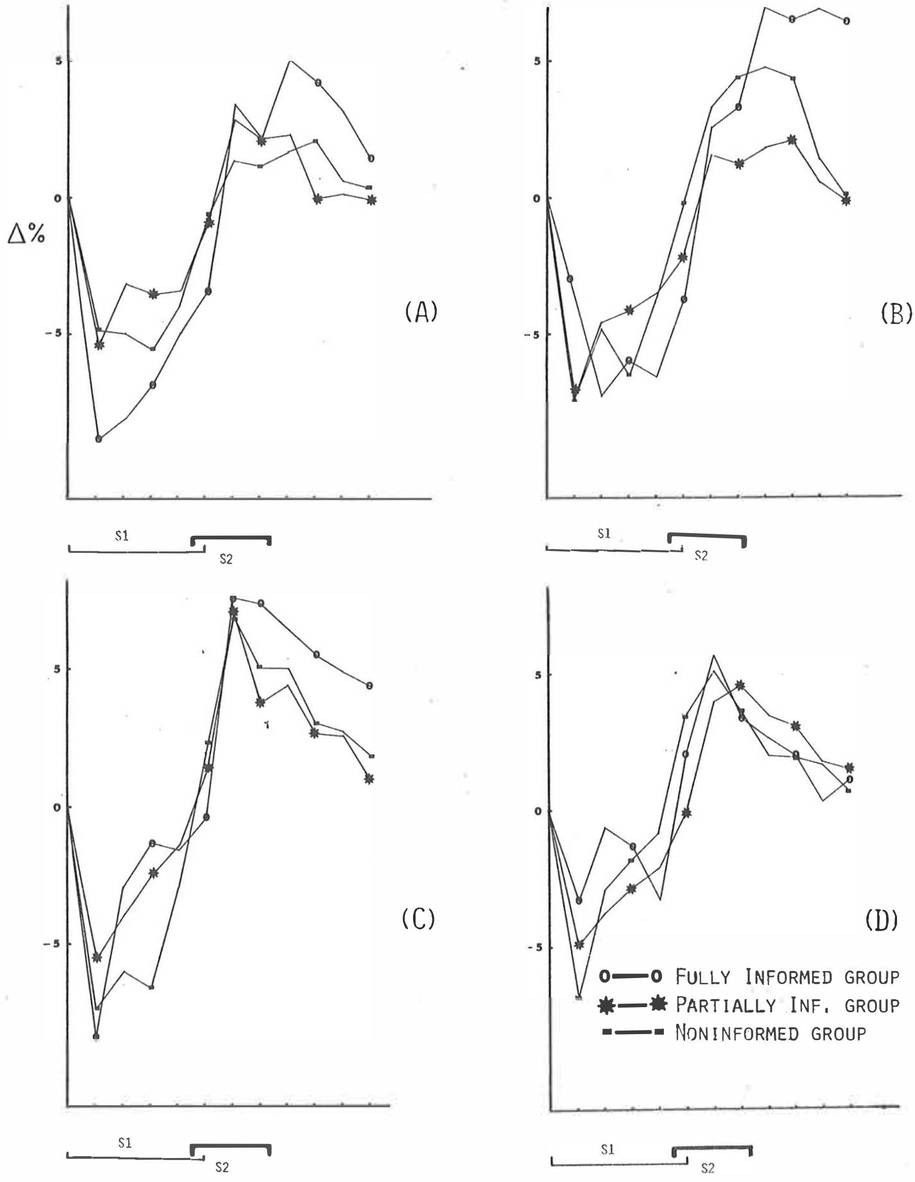

Figure 13. Changes of pupillary activity in (A) Sensory, (B) Memory, (C) Motor and (D) shock-Stimulus conditions in Fully Informed, Partially Informed and Noninformed groups.

was found during the pre-S2-period. The F-values of these changes between measuring intervals ranged from 34 to 64 (cons df 1,27 and ps <.000), but only Fully Informed group displayed dilation patterns which showed significant condition-specificity.

The pre-S2 dilation followed in all groups mainly a linear trend (Fs of linear component ranged between 80 and 112) but there was also a moderate quadratic component in the curves (Fs of this component ranged between 13 and 64). Furthermore there were trends of other types too, which were group- and condition-specific. Thus the Noninformed group displayed in all conditions some cubic trend due to a little dilation during the middle of the S1-S2 interval, but in the Fully Informed group this change-component was also found in three conditions, viz. in shock- and tone-Stimulus and Motor conditions. In Motor condition the cubic form of the dilation in Fully Informed group reached a level which made it more pronounced than that of Noninformed group (difference in the cubic trend F=7.260, df 2,27, p <.01). See Figure 13.

During S2 conditions differed significantly (F=7.240, cons df 1,27, p <.01). The dilation were larger during Arithmetic, Memory and Motor tasks than during Stimulus- and Sensory conditions. The pupillary diameter variation revealed also an information-relatedness effect in Memory condition (F=4.07, cons df 2,27, p <.05). The Fully Informed group responded with more pronounced dilation as can be seen in Figure 13.

3.2. Summary of univariate results

It was hypothesized that physiological arousal fractionates into a multidimensional array of ˊarousalsˊ which manifest specificity according to realized and anticipated situational demands.

Demonstration of a specificity in responsivity to the sampled six types of S2-events can be thought of as a sine qua non for empirical verification of specificity in the related pre-S2 responses, ie. preactivity. Confirmation of this latter specificity in turn is an empirical way to substantiate expectations concerning the defined ˊgoal-directedˊ nature of pre-event activity or to establish its validity as a manifestation of anticipation.

Thus the object of summarizing evidence from the present univariate results is to document the sensitivity of each physiological variable to: 1) contrast the conditions including different demands with S2-produced (third-interval) responses 2) manifest condition-specificity already before the onset of the critical event in the first- and/or second-interval responses as a function of advance information.

Answering the first point presupposes inspection of the main effects of conditions in ANOVAs of (third-interval) responses to the critical events (S2), which are ´physically´ the same in all groups. Interaction terms of the analyses of the pre-S2 data (with respective mean comparison results) offer a statistical basis for documenting the second point.

The results also permit a preliminary summary of the differential sensitivity of the two pre-S2 response components to contrast the conditions (ie. to manifest demand-specificity). More sensitive statistical contrasts can be made, however, only in the context of the multivariate analyses. The differential suggestibility of the two pre-S2 response components to the repetition effect (ie. habituation) and thus their relation to this critical feature of orientation reaction can be evaluated on the basis of the main effect of trials and interaction effects between trials and these two response intervals from the groups x intervals x trials ANOVAs.

The third object of summary statements concerns the preception hypothesis and requires detailing the effects information has on the activity accompanying and following S2-event especially in the preception sensitive conditions, the most documented of which is shock-Stimulus condition. Conclusions can be based on the main effects of groups and related interaction effects with conditions.

Table 1 summarizes the results related to these three questions. The first column catalogues the variables measured in the study. The second (a) mentions those conditions which consistently show more than mean or less than mean activity during the critical event (S2). The third column (b) displays conditions in which pre-S2 responses show significant S2-specificity in the informed but not in the noninformed group(s) and the associated interval (first=1, second=2). The column (c) displays the S2-events, responses to which are attenuated as a result of advance information.

3.2.1. Univariate contrasts in responses to different S2-events

The criteria for a conclusion that a condition has a tendency to elicit more or less activity than others in a variable are either the significant main F

Table 1. Summary of the main univariate results

Physiological variable	Conditions in which the variable shows				
	(a) S2-produced tendency to increase	/ no change	(b) Pre-event contrasts in FI-group	interval	(c) attenuated S2-responses as a result of advance information
SCR	Mo,sS,Ar	Se	sS,Mo>other Mo,Ar>Se,tS	1 2	Mo, sS, (tS)
FPA	Mo,Ar,Me	Sc	Mo>other	2	All*
HR	Ar,Me,Mo	tS	Me,Ar>sS,tS	1,2	(Mo,Ar)
Respiratory disturbances	Mo	(Ar,Me,Se)			All*,Mo,sS
cycle durat.	sS,tS	Mo	(Ar,Me>Mo)	1	
BV constr.	sS	Ar	Mo>Ar	1-2	
BV dilation	Ar				(sS,Mo,tS)
Flexor EMG	Mo,sS		Mo>other	1,2	sS
Frontal EMG			(Mo>sS,tS)	1	sS
Orbic. EMG	Mo,Me	Se,tS, sS	Ar,Me,Mo>sS,tS (Ar,Me,Se>tS)	1 2	Se, (tS,Mo)

Parentheses refer to conditional effects (see text for details)
* Relevant main effect of information is significant

of conditions with Newman-Keuls focusation of the contrast or, in the case of significant interaction, at least one significant effect in the pairwise comparison of conditions plus a consistent position of the condition in the groups.

Table 1 reveals that skin conductance, pulse amplitude, heart rate, flexor and orbicularis EMG are especially responsive to motor event. No variable is significantly less responsive to motor demands than to any other condition. The typical UCS, electric shock, elicits activity in skin conductance, respiration, flexor EMG and blood volume (constriction). Cognitive conditions (Arithmetic and Memory tasks) are accompanied by constriction in pulse amplitude, increase in heart rate and orbicularis oris EMG (particularly in Me in the form of less decrease), respiratory changes and blood volume dilation. The tone Stimulus and Sensory task are the most neutral conditions for most of the variables.

The results offer no apparent support for any unidimensional construct of arousal; different conditions are accompanied by different patterns of physiological arousals. The differences surpass the similarities. Thus, sorting of the conditions into any order with respect to some dimension of requirements for ´energy mobilization´ fails to uncover even roughly any such consistency between the measures which an assumption of unidimensionality of the physiological arousal would presuppose. The third-interval results demonstrate with the present sample of S2-events sufficient event-specificity to allow a strong case for expecting event-related anticipatory ´arousal´ also in the pre-S2 activity.

3.2.2. Pre-event activity

Conclusions about the variable´s tendency to show specificity in the pre-event responses will be based on the following criteria. There must be 1) a significant groups x conditions interaction and either of the two significant mean comparison results: 2a) in group-specific post-hoc comparisons a significant between-condition difference which appears in both informed or at least in Fully Informed group but not in either of the noninformed groups and/or 2b) in condition-specific comparisons difference between the two main, Fully or Partially Informed vs. Noninformed or Sensitization, groups so that at least one member from both sides is represented.

Some evidence about preactivity fulfilling the above criteria is found in all main physiological variables except respiration and frontal EMG. Also these variables display some but less consistent evidence about pre-event specificity. In most variables these contrasts are significant between those conditions, which also have produced differential post-S2 responsivity as can be seen in Table 1 by comparing the first and second columns. Thus when skin conductance is most responsive to motor activity demands and to electric shock, these same conditions are accompanied by greater pre-event activity than the other conditions in Ss sufficiently informed for predicting the critical events correctly. Similarly the events most suggestible to produce change are in pulse amplitude Motor condition and in heart rate the cognitive conditions each manifesting this tendency during both execution and preparation.

In some variables the pre-event activity seems to show a stronger tendency to contrast the conditions than do the S2-produced responses. These are, however, rare exceptions resulting more likely from insensitivity of statistical tests; in all those cases the S2-profiles tend to be quite similar to the pre-S2 ones. The clearest exception is the orbicularis oris EMG increase which accompanied preparation for Arithmetic tasks more clearly than its execution.

On the other hand the manifested sensitivity of a variable to respond differentially between ´realized demands´ (ie. to contrast S2-events) did not necessarily always result in the same contrast in the preactivity. Thus the respiratory behavior towards the realized and anticipated events differed markedly and a discrepancy could be also found in the blood volume changes, which did not behave very reliably in any condition. However, also in the last cases the shapes of the profiles across conditions were quite similar during pre- and post-S2 intervals.

The results displayed moderate communality between the responses measured during the first and second intervals as can be seen in Table 1. In the orbicularis oris and flexor EMG-measures both components showed the same contrast-pattern. In some cases there were consistent between-condition mean differences which did not reach significance but the means of also these responses showed mostly the same order of differences as did their significant counterpart in the other of the pre-S2 intervals. This tendency was especially clear in skin conductance in which second-interval contrasts were more consistently significant. Pulse amplitude and volume seemed to be too slow to change to allow consistent division into two response components within so short a time.

Conclusions related to the differences of the two pre-event components in their ability to contrast conditions are left to the context of summarizing the results of multivariate analyses which offer more adequate statistical means for such comparison.

As far as the first-interval response is thought to reflect characteristics of orientation response it should be sensitive to change as a function of trial repetition (ie. habituate). Evidence in line with this expectation was found in three measures: 1 skin conductance, 2 pulse volume and 3 heart rate deceleration. All of them revealed significantly more habituation during the first than during the second interval of ISI. In only one variable, respiratory cycle duration, both of the intervals revealed significant change as a function of trials.

3.2.3. Effects of advance information on the S2-elicited responsivity

The response to the critical events was presumed to be dependent on the advance information Ss had about them. Prewarning was assumed to reduce the S2-produced responses in sS condition according to the negative preception-hypothesis.

Skin conductance, respiratory disturbances and EMGs, especially frontal EMG all displayed significantly more activity as a response to shock in the less informed than in the more informed groups. In all the evidence was quite strongly in line with the hypothesis. Of the nine main variables four showed consistent statistically significant patterns of differences in the expected direction. Most of the other comparisons showed a mean order in the expected direction although the differences failed to achieve significance. In the case of skin conductance, respiratory disturbances and frontal EMG, the evidence was most consistent because in those variables both informed groups responded less to sS than both noninformed groups. In the case of pulse amplitude constriction only NI-PI contrast achieved significance. In this variable, however, NI group responded with larger constrictions to all S2-events. Blood volume responsivity tended to be more pronounced especially in the SE-FI comparison. SE group responded more in all potentially relevant conditions (viz. sS, tS and Mo).

There was some evidence about a preception effect also in the other conditions. Thus in tone-Stimulus condition skin conductance, and flexor and orbicularis oris EMG displayed less increase (or more decrease) in the informed groups. Pulse amplitude constricted more, heart rate accelerated more, respiratory disturbances were more frequent and orbicularis oris activity more probable in the Noninformed than in at least one of the more informed groups in the Motor condition.

A significant but opposite relationship tended to appear in the responses of Sensitization groups to the cognitive tasks. Thus SE displayed significantly less heart rate acceleration during cognitive tasks and the same appeared also as lower concomitant probability of flexor EMG increase in this group. In Memory condition this group responded also less in orbicularis oris EMG.

These can be explained as results of lesser involvement of this group in the events presupposing active performance, as will be detailed later.

Overall, the results concerning the S2-elicited activity thus favor a contention that advance information tends to diminish not only the unconditioned responsivity but also 'arousals' accompanying executive activity, especially during motor demands. This concerns at least such a motor activity which can be performed in a more controlled manner, if preparation for it is allowed, as was the case in the present motor task. Some types of mental activities may also benefit from the activatory preparation which the advance information may offer for them. This is supported by the higher responsivity of the informed groups to cognitive S2-events.

The results describing the behavior of single variables may, however, fail to detect significant information included in the patterns of the measured physiological variables. Therefore these univariate analyses are supplemented with multivariate evaluation of the patterning of variables.

3.3. Multivariate results: Experimental effects on patterning of physiological arousal

Thus far the analyses have concerned variable-specific effects. Comparison of these findings gives cause to expect that some effects have such a multivariate nature that variables pattern together differently depending on the condition. For example, inspection of Table 1 leads one to suppose a compounding of skin conductance, pulse amplitude constriction, heart rate acceleration and flexor EMG to accompany motor execution. All of these were especially responsive during motor execution. Similarly univariate analyses suggest covariant changes of heart rate, respiratory disturbances, orbicularis oris and vasoconstriction during cognitive performance. Univariate results support an expectation of similar condition-specific patterning of the pre-S2 activity and do so more clearly the more information for correct anticipation of events has been available. Similarly the preception effect was found above to be associated with several variables, thus making an assumption about reliable multivariate patterning viable. Multivariate analyses will also disclose possible redundancies between measures thus contributing to answering in part the questions about independent dimensions of physiological 'arousal'.

As a first step an examination of general patterning of phasic physiological activity was made by running principal component analyses (PCA). Second, stepwise discrimination analyses (SWDA) were computed to show how the S2-evoked response patterns could be contrasted according to the demands included in the six different S2-types. The third task was an explication of the respective contrasts between response profiles emerging from the differential demands as these appeared in the pre-S2 intervals in the different groups. Comparisons between groups were made to detail how the information available in advance about S2 increased this specificity.

To characterize the preactivity in relation to features of arousal typically associated with orienting reflex (OR) vs. anticipatory preactivity, respective stepwise discriminate analyses were performed with scores of both of these intervals separately.

The last object of multivariate evaluation was the characterization of effects of information on the S2-patterns. This was made by computing stepwise discrimination analyses between groups with third-interval data. The focus of special evaluations in this last context was how the preception-effects, whose existence was shown with univariate analyses, would appear in the patterning of the variables.

3.3.1. General patterning of the physiological activity

Independent of the data selected for analysis (eg. the third-interval scores of total N or of each group separately, or scores of all intervals from all groups) the main structure of the principal component factors displayed about the same general form. The results from the analysis of the total data are examined below in more detail.

An overview of the correlation matrix (Table 12 in Appendix 2) already reveals that there was not much common variance between the separate physiological variables although the manipulation of the ´arousal´ was quite intensive for uncovering the existence of any common arousal-dimension. The highest correlations of the physiologically separate variables vary between r 0.10 and r 0.27 and have quite a narrow range as can be seen in the above cited Table.

The maximal between-interval correlations within physiological variables varied from low in blood volume (r 0.13) via moderate (in most variables, eg. in EMGs between r 0.60-0.66) to high in respiratory duration (r 0.90). The correlations between different scores of the same physiological variable

Table 2. The principal component structure and varimax-rotated matrix of the S2-activity with all main variables as input

Principal factor matrix

Variable	Factors 1	2	3	4	5	6	7	Communality
Pulse amplitude	-.25	-.28	.23	-.37	.42	-.07	-.15	.55
Skin conductance	.13	-.08	-.03	.24	-.60	.40	.26	.69
Heart rate peak	.84	.35	.15	-.03	.15	.09	-.15	.92
Heart rate mean	.82	.37	.14	-.06	.12	.11	-.16	.91
Resp.disturb.	.18	-.31	.61	.37	.13	.06	-.00	.68
Resp.cycle durat.	-.06	-.42	.62	.30	.07	.07	.08	.67
Flexor EMG	.21	.14	-.04	.17	.25	-.39	.76	.87
Frontal EMG inc.	.39	-.51	-.40	.02	.29	.20	.22	.77
Frontal EMG dec.	-.27	.61	.33	.12	-.19	-.37	.04	.77
Orbic.EMG dec.	-.29	.47	-.01	.11	.43	.40	.29	.76
Orbic.EMG inc.	.49	-.31	-.11	.03	-.19	-.58	.00	.74
Blood volume dec.	-.01	.07	-.26	.69	-.01	.06	-.27	.64
Blood volume inc.	.15	-.02	.29	-.49	-.39	.24	.28	.65

Varimax rotated factor matrix

	1	2	3	4	5	6	7
Pulse amplitude	-.17	.11	-.07	.17	.20	-.65	-.15
Skin conductance	-.06	.10	-.00	.10	.14	.80	-.08
Heart rate peak	.95	.04	.06	.02	.03	.03	.05
Heart rate mean	.95	.03	.05	-.01	.04	.05	.02
Resp. disturb.	.14	.02	.05	.81	-.05	-.00	.02
Resp. cycle dur.	-.14	.01	.01	.81	.04	-.02	-.00
Flexor EMG	.05	.01	.00	.02	.02	.03	.93
Frontal EMG inc.	.07	.84	.09	.01	-.05	.03	.20
Frontal EMG dec.	-.00	-.85	-.72	-.03	-.04	.02	.19
Orbic. EMG dec.	.02	-.06	-.83	-.07	-.09	-.04	.23
Orbic. EMG inc.	.14	.11	.80	.00	-.05	.02	.26
Blood volume dec.	.01	-.00	-.04	.05	-.74	.28	-.10
Blood volume inc.	.08	-.02	.01	.03	.76	.25	-.08

within the same interval correlated quite highly eg. between HR peak and mean (r 0.73-0.95) or moderately eg. between EMG-decrease and increase (r -0.24- -0.50).

As could be expected from such a correlation structure, the analyses performed with the total arsenal of interval-specific scores produced factors combining measures within the physiological variables rather than revealing any broader compounding of different arousal-measures. Table 2 illustrates the factor structure which is based on the generation of factors up to the point at which eigenvalue reaches the 1.0 level. Seven factors were found which explain 74.1 % of the variance, first 16.5, second 12.6, third 10.1 and the four last factors 8-10 percent of the common variance each. As can be seen each factor compounds quite unambiguously the different measures of the same physiological variable in all but one case: skin conductance and vasomotor variables pattern together to form the sixth factor.

The principal components are, both before and after rotation, quite specific. The resulting factor structure fails to display evidence of sharing of variance between measures thought to covary in reflecting any general arousal dimension consisting of eg. HR, FPA, SCR and frontal EMG. No unitary arousal model fits in the component structure to explain the patterning. Also the existing covariance is low as verified by the maximal correlations between the different variables loaded in the same unrotated factors. Even the EMGs offer quite nonredundant information; the maximal correlation between concomitant scores is between flexor and orbicularis increase during the third interval (r 0.22). The highest HR-EMG correlation is between orbicularis oris increase and HR peak-change r 0.27 and between HR and respiratory variables: between duration of the respiratory cycle and the same HR-peak measure -0.14. In the factor structure the clearest indications of concomitant variation between different ´arousal´ variables appeared between skin conductance and pulse amplitude constriction, which compounded to the same factor. However, also these variables correlated quite lowly. Their highest correlation appeared during the second interval and was r 0.18 and other rs were 0.11 (1.) and 0.15 (3.).

In sum, the above results allow a conclusion that the principal components derived from the present data make possible a reduction of variables within physiological response channels but not across these without losing potentially important information. Further PCAs were performed with data in which each channel was represented by one measure or two scores which were not too redundant.

Results from analyses of third-interval scores are reported here as an example and because of the potential applicability of such data reduced in terms of factor-scores for a summary of experimental effects on S2-activity. An overview of findings with respective reductions computed from the data of the pre-S2 intervals made clear that too much significant information is lost to continue their analysis with means of the factor scores.

PCA-runs performed with different sets of third-interval variables

Table 3. The principal component structure of the S2-activity with selected variables as input

Principal factor matrix

Variable	Factors 1	2	3	4	Communality
Pulse amplitude	-.28	.15	-.53	.52	.65
Skin conductance	-.01	-.51	.54	.03	.56
Heart rate mean	.89	.02	-.12	-.11	.81
Heart rate peak	.91	.02	-.05	.03	.84
Flexor EMG	.31	.37	.37	.26	.43
Respiratory dist.	.15	-.07	.19	.84	.76
Frontal EMG	-.10	.70	.24	-.12	.57
Orbicularis EMG	-.06	.67	.12	-.03	.47
Blood volume	-.15	-.01	.66	.04	.47

Varimax rotated matrix

Variable	1	2	3	4
Pulse amplitude	-.30	-.04	-.65	.38
Skin conductance	-.06	-.33	.66	.13
Heart rate mean	.90	-.03	-.07	-.03
Heart rate peak	.91	-.03	-.02	.12
Flexor EMG	.28	.43	.19	.37
Respiratory dist.	.05	-.07	.05	.87
Frontal EMG	-.07	.75	.03	-.07
Orbicularis EMG	-.04	.68	-.09	-.01
Blood volume	-.19	.19	.60	.15

revealed that by far the best reduction could be achieved by representing each EMG with the decrease-variable (which were also more sensitive to experimental manipulation), blood volume with dilation (for the same reason), heart rate with the two variables (because this increases the explainable variance and adds information about experimental effects) and excluding respiratory cycle duration (because of low communality) from the analysis.

A principal component analysis of the thus selected nine variables revealed, both with oblique and varimax rotation, four significant factors before eigenvalue dropped below 1.0. Table 3 illustrates the results. Factors explain 41 % of the total variance included in the variables and the four factors explain 21, 15, 14 and 12 percent of the common variance each, respectively. The first rotated factor clearly represents cardiac activity, the second EMG-responses, the third compounds SCR, FPA and BV-variables.

The last (fourth) factor has its highest loading in respiratory disturbances but FPA and flexor EMG have also moderate loadings.

An analysis of variance with the factor scores calculated on the basis of this factor structure established that these factors represent quite well the main variance which differentiates both the groups and conditions from each other. Comparison with univariate results revealed, however, that some important details are faded out and thus these reduced factors can be used only with great care. For example the preception-sensitive variables distribute to different factors so that a significant groups x factors interaction (F=5.96, Lh df 3,76, p <.001) is achieved. It results from the difference between the two main groups (SE,NI vs. FI,PI) as expected, but concerns only one, (the second) EMG/decrease-factor. The other, verifiably more sensitive variables (although condition-specifically, see Table 1), are scattered out. The effect on the EMG-compound seems to be general enough over conditions to surpass the effect of pooling the conditions. Also the first, HR-factor, reveals one significant difference which contrasts Sensitization group with the others. This effect was disclosed also in the univariate analyses, but there an important interaction with conditions was also found. Factor scores have lost this property to indicate interactions with conditions and make the results difficult to interpret. Thus the psychologically informative specificity of the measured variables does not allow even this type of reduction of 'arousal' to the four main dimensions. The above results establish that interpretational clarity makes it necessary to continue analysis with the primary variables.

Overall the PCA-results support unequivocally the hypothesis that the variance of the typical psychophysiological measures cannot be reduced to a single arousal dimension(s) without losing significant information included in it (them).

3.3.2. Patterning of physiological activity as a function of S2-contents

The subsequent analyses were performed to detail the compounding of physiological responses to form multivariate patterns specific to conditions and to the temporal phase (interval) of their occurence during the trial. This was done by running stepwise discrimination analyses (SWDA) to contrast the conditions on the basis of data of each interval separately. The first SWDAs were computed with the third-interval data for detailing effects of 'realized' demands.

Generally these results disclosed, like the univariate findings, that most variables contributed significantly in the discrimination between conditions. Multivariate results established that variable-compounds differentiate conditions more clearly than any single variable, ie. the significant variance of the different variables is not redundant, but most of these make an independent contribution to explaining the experimental effects.

Of the main variables (see Table 4) only respiratory cycle duration failed to contribute independently to the multivariate contrast between conditions. The two EMG-measure pairs (increase/decrease of orbicularis oris and frontal muscles) were found to be so redundant that typically only one member contributed independently. Thus orbicularis oris increase was not entered into analysis when the stepwise procedure was set to apply an F >1.0 removal criterion. All other variables passed also a F >2.0 criterion.

The comparison of conditions with multivariate (Wilks´ Lambda based) F-statistics established that only the two cognitive (Ar and Me) and the two Stimulus (sS and tS) conditions failed to be differentiated from each other very significantly (ie. Ar from Me and sS from tS). The difference between Memory and Sensory condition was significant on the p <.002 level and all other twelve comparisons achieved very significant contrasts (p <.000). The canonical correlations of the three significant discriminant functions (r 0.68, r 0.57 and r 0.25) explained 85 % of the variance included in the dummy based logical contrasts between the six conditions.

The varimax rotated function axes located the first contrast between 1) Motor vs. cognitive (Me,Ar) conditions. Motor task had a centroid value of 1.8, cognitive conditions -0.67 and -0.56 respectively for Me and Ar and stimuli 0.18 (sS) and -0.25 (tS).

The second function contrasted Cognitive and Motor conditions against Stimulus conditions (sS and tS). The mean centroid values of Cognitive and Motor conditions ranged between 0.54 and 0.66 and the respective values for Stimulus conditions were -0.77 (tS) and -0.69 (sS). Sensory condition fell between them with a value of -0.19.

The third function had its highest centroid values in Motor task (0.59) and sS-condition (0.35). Arithmetic task was in the middle (0.09) and Sensory task was lowest (-0.66).

The respective ´latent factors´ behind the distributions on the conditions might be characterized according to their most positive centroids; ´motor activity´(1), ´effort´ (2) and ´general arousal´ (3), respectively. The related

Table 4. Summary of discriminant analysis of the S2-activity with condition-contrasts (all main variables as input)

Variables in the analysis after step 11

Variable	F to remove	Wilks´ lambda
Skin conductance	11.6510	.371
Pulse amplitude	3.2864	.341
Heart rate peak acceleration	3.2397	.341
Heart rate mean change	7.1213	.355
Respiratory disturbances	4.4143	.345
Flexor EMG increase	51.3480	.512
Frontal EMG increase	1.3563	.334
Frontal EMG decrease	2.9003	.340
Orbicularis oris EMG decrease	2.0203	.337
Blood volume dilation	3.2400	.341
Blood volume constriction	3.8329	.343

F statistics and significances between pairs of groups after step 11 (each F statistics has 11 and 464 degrees of freedom)

Condition	Sensory task	Shock-UCS	Ment.arit. task	Memory task	Motor task
Shock-UCS	7.0413				
	.0000				
Arithmetic task	6.1915	13.9330			
	.0000	.0000			
Memory task	2.7930	11.2280	1.3545		
	.0016	.0000	.1915		
Motor task	24.4610	13.6700	23.5910	24.3570	
	.0000	.0000	.0000	.0000	
Tone-UCS	4.8229	2.1054	14.1240	10.0010	22.1580
	.0000	.0188	.0000	.0000	.0000

Canonical discriminant functions (CDFs)

Function	Pct of var.	Can. corr.	Wilks´ lambda	Chi-sq	df	p
0			.330	521.50	55	.0000
1	59.20	.677	.610	231.88	40	.0000
2	34.07	.573	.909	44.385	27	.0189
3	4.49	.246	.968	14.954	16	.5280
4	1.41	.141	.988	5.5011	7	.5991
5	.82	.107				

physiological patterns were quite clear. The ´general arousal´ function was contributed mostly by variables used to associate with such a function viz. skin conductance and vasoconstriction; also blood volume constriction made a contribution. The ´effort´ function axis was based on HR- and orbicularis oris EMG-increase (or lack of decrease) and the motor function was almost totally explained by flexor EMG, only frontal EMG had some minor additional role in it.

If the analysis is run without flexor EMG the position of Motor condition changes. F-values in the contrast-table reduce from the class of 15-20 to 5-10. The third function loses its significance and the first and second function exchange places. The present third function is mixed with the second in such a way that skin conductance reaches a dominant position there. At the same time sS condition achieves the centroid value equal with Motor condition in the second function.

The functional roles of heart rate and skin conductance are shown to differ clearly judging by the consistently dissimilar correlations with axes in each analysis. Flexor EMG deviated from both of these, but HR and orbicularis EMG had parallels especially to the axis contrasting the cognitive and Stimulus conditions. SCR and pulse amplitude as well as blood volume also showed patterning in contrasting Motor and shock UCS-conditions from the others in the first analysis.

Thus the demands imposed by the main S2-types were manifested in differentiable physiological patterns as was expected. The multivariate results establish that the different condition-specific responses figured in the univariate analyses make significant independent contributions in differentiating responses characterizing activity in each condition instead of redundantly reflecting some common latent factor. These findings offer an adequate background for searching for condition-specificity also from the pre-S2 activity.

3.3.3. Patterning of the pre-S2 activity as a function of anticipated demands

Stepwise discrimination analyses (SWDA) were performed with data of each group separately to examine whether or not the pre-S2 response-compounds succeed in contrasting the conditions in the groups according to the following hypothesis: contrast increases as more advance information is made available for correct anticipation of the S2.

Table 5. Summary of selected parameters of discrimination analyses contrasting the conditions with the two pre-S2 interval scores of the 13 main variables in each group separately. Related parameters of the third components are included on the lowest row for comparison.

Group code	Number of variables with F>2 to remove	the differentiable conditions p<.01&	Canonical correlation with respective discriminant functions* 1 2	1 2	1 2 3	Percentage of explained variance
Comp.	1,2 (1+2)	1, 2 (1+2)	1	2	(1+2)	1, 2 (1+2)
FI	6,5 (11)	7,10 (12)	60,56	66,49	(61,52,40)	66,68 (80)
PI	0,2 (6)	0, 7 (8)	-	52 -	(41,31)	-,27 (27)
NI	1,2 (3)	0, 3 (3)	- -	47 -	(35,32)	-,22 (22)
SE	2,1 (6)	1, 0 (8)	44,37	46 -	(40,31,30)	33,21 (35)
SE1a	2,3 (6)	1, 3 (8)	- -	56 -	(52,36)	-,32 (40)
Comp.	3	3			3	3
All groups	10	13			68,57,25	85

& From the 15 possible pairwise comparisons of the six conditions.
* Decimal points deleted (56=0.56).

It is shown first in detail how the informed groups display condition-related patterns according to the future S2 with first- and second-interval responses. As presented in the first data-row of Table 5, both of these scores of Fully Informed group discriminated also singly very successfully the conditions.

The maximal contrasts computed from scores of the informed groups classify the conditions into three main groups irrespective of the interval used as data: (1) Cognitive conditions (Ar and Me), (2) Stimulus conditions (sS and tS) and (3) Motor condition. As found also in analysis of S2-data, Sensory condition proved to be a mixed entity in relation to arousal patterning, associating partly with cognitive and partly with Stimulus (especially tS) conditions. However, it differed significantly from Motor and sS-conditions.

Two significant discriminant functions achieved a very satisfactory explanation of the first-interval preactivity patterns of FI-group. The first function differentiated cognitive (centroid values -0.90 in Ar and -0.60 in Me) from Motor (1.04) and sS-condition (0.87). The last two conditions (Mo ans sS) were differentiated by the second discriminate function. The standardized canonical discriminant function coefficients revealed that skin conductance (0.77), flexor (0.57), orbicularis oris EMG (-0.49) and HR (-0.49) made the highest contributions to the first function. Correlations of the variables to the canonical discriminant functions showed that SCR increases in the direction represented by Mo/sS in the axis (r 0.47) and at the same time the probability of orbicularis oris EMG-increase becomes lower (r -0.41) and that of flexor EMG higher (r 0.39).

The second function, whose centroid values were sS (0.95), tS (0.57) at the positive end and Motor condition (-1.12) at the negative end, was contributed to most by orbicularis oris decrease (0.68), flexor EMG-increase (-0.61) and blood volume dilation (-0.57). Respective highest correlations were with flexor EMG (-0.53), frontal EMG increase, (-0.43), orbicularis oris decrease (0.40) and blood volume increase (-0.40).

The classification results were quite complete. Cognitive conditions were misclassified to Motor ones in 5 or 0 % of comparisons for Ar and Me, respectively. Similarly sS and Motor conditions were mixed only in 5 % of cases. Lowest classification success was between Se- and Me-conditions. The first was predicted to be Me in 25 % of comparisons. Mo was never mixed with Se or tS and sS never with Se or Ar. Surprisingly, the cognitive tasks were also quite well separable and were mixed with each other only in 15 % of the comparisons.

As shown in Table 5, the second-interval data slightly exceeded that of the first in its information content for contrasting the conditions. There were, however, only minor differences in the contributions of the single variables. The main difference was that flexor EMG contributed relatively more strongly to the discrimination between cognitive and Mo- &sS-conditions. The mean classification success was the same in the data of both of the pre-S2 intervals.

Combining the data of the two intervals in the analyses sharpened the achieved between-condition contrast markedly. Thus the number of entered variables increased from 6 to 8, and explained variance rose from 68 to 80 percent thus approaching the level reached with the third-interval data (whose corresponding parameters were 10 and 85 % , respectively). The similarity between the pre- and post-S2 response patterns also was highest when comparing the latter with results from SWDA which was performed with combined pre-S2 (intervals) data.

3.3.4. Comparison of the patterns of pre-S2 intervals

A further SWDA was performed for comparing in more detail the information value of the two pre-S2 components in contrasting the conditions. First- and second-interval scores of each variable of the Fully Informed group were used as separate input-variables. The results revealed that of the fifteen (from 23 stepwisely given and with removal criterion of F>1.0 entered) variables nine represented the first interval and six the second interval. The two largest F-to remove values were in the second-interval variables, FPA and flexor EMG, but FPA was not until third in order of entering into the equation. As can be seen in Table 5 the two intervals contributed about equally in the contrasts of the conditions.

The same analysis performed with Partially Informed groups, however, showed that, if the S1 information was not immediately clear to subjects (as is the case in PI-group), the specificity was delayed until the later phase, ie. the second-interval scores achieved a more central role in contrasting the conditions, as seen in Table 5.

The maximal contrasts between conditions are found in FI-group between Motor and other conditions (first function-axis) and between Stimulus vs. other conditions (second axis). The first contrast is contributed to most by the immediate changes of heart rate after the onset of S1 and second-interval score of vasoconstriction. The thus construed discriminant function correlates most highly to flexor activity of both intervals as displayed in Table 6.

The second contrast appearing between anticipation of stimuli vs. tasks is found to be largest when the information included in the immediate, first-interval skin conductance, orbicularis and flexor and flexor responses (to the direction of decrease) are weighted in the SWDA-equation. This weighting produces an axis which correlates most strongly to orbicularis EMG-changes during both intervals as shown in Table 6. This all strongly supports a contention that in FI-group already the immediate responses to S1 are ´directed´ to coping with the demands S2 include. First-interval response-information suffices in achieving significant contrast between the conditions.

An inspection of the SWDA-results of Partially Informed group in Table 6 reveals that the first contrast differentiates sS and Motor conditions from others. This follows mainly from a contribution of the second-interval skin

Table 6. Summary of discrimination analysis contrasting the conditions with the two pre-S2 interval scores of the two informed (PI and FI) groups.

Group	SWDA-parameters													
	Function	Multiple	Centroid values of the conditions						Largest stand.discr. function coefficients			Largest correlations with discr. functions		
		R	Ar	Me	Se	sS	tS	Mo	1.	2.	3.	1.	2.	3.
FI	I	73*	58	53	76	-19	55	-223	FPA2§ 74	HRp1 -63	HRm1 62	fIEMG2 -47	fIEMG1 -41	FPA2 40
	II	65	-60	-96	-28	136	86	-39	SCR1 67	orEMGd1 49	fIEMG1 -48	orEMGi2 -51	orEMGi1 -45	orEMGd1 38
PI	I	63	38	89	45	-127	41	-86	SCR2 -82	fIEMG2 -74	HRm1 -71	HRp2 42	SCR2 -41	HRm2 38
	II	55	69	76	-80	25	-80	-08	HRm2 92	orEMGd1 74	SCR1 -63	HRm2 50	HRp2 41	orEMGd1 32

* Decimal points deleted (73=0.73).
§ See abreviations in Appendix 1.

conductance and flexor responses. The resulting axis correlates most with the second-interval heart rate and skin conductance changes. The second function differentiates cognitive and Stimulus conditions and is maximally contributed to by pre-S2 heart rate mean but also by first-interval orbicularis oris decrease and skin conductance responses (negatively in the latter case). There is only one first-interval variable in the three highest correlations. All this shows that in Partially Informed group the later activity in the ISI clearly contrasts the conditions more effectively than the immediate responsivity to S1-onset.

Overall the present data are not compatible with a contention that the immediate autonomic-somatic responsivity to S1 represents a nonspecific orienting activity. Rather, it clearly is specific in nature in the sense of manifesting patterning which is determined quite conclusively not by the demands to prepare generally for future challenges but specifically for the expected event.

3.3.5. Effects of information on the specificity of the pre-S2 patterns

Table 5 illustrates how the data lose their property of reflecting a contrast between the S2-events as a function of reduction in the advance information. The response patterns of Fully Informed group achieve a statistically significant contrast in 12 of the possible 15 pairwise comparisons, Partially Informed groups in eight and Noninformed only in three condition-comparisons.

Sensitization group responded with slightly higher specificity than Noninformed groups which might be expected because two thirds of SE-group's Ss had the information in their S1-labels. The possibility that the information slide without paired S2 was sufficient to produce the specificity was examined by running a SWDA with data of those members (N=13) of Sensitization group who had S2-information (codes or labels) in the S1-slides. Respective discrimination parameters (see SEin row in Table 5) from this analysis reveal, however, that this information as such has only a slight effect on producing contrast between conditions.

Discrimination analysis with the data of Partially Informed groups clearly succeeded less well in discriminating conditions than FI-group. This together with the above results from the SE-subgroup with S1 labels allow an important conclusion: the labels as such are not sufficient stimuli for eliciting specific response patterns; anticipation of an immediate occurrence of the related event is also necessary. In the last case the specificity appears within the latency of the immediate response if the advance information is explicit, otherwise with a delay needed for correct 'anticipation'. Thus the task of deciphering the S1-code and consequent processing and decision making activity made Partially Informed group respond more nonspecifically during the first interval. At least partly, however, the second-interval activity already reflected the anticipation of the critical S2 event because it was clearly specific to its content.

3.3.6. Patterning of information-related S2-activity

The first question concerning the effect of advance information on S2-activity deals with the general expectation that uncertainty has some cost in 'energy consumption' during task-execution/experience of stimuli. As shown by the univariate analyses eight of the thirteen single variables displayed some significant group-related differences in the S2-activity in the direction of this expectation (see Table 1).

Compared to the informed groups Sensitization and/or Noninformed group displayed significantly larger or more frequent responses generally or condition-specifically practically in all main variables in some way. Noninformed group responded consistently with larger FPA-constriction to S2. The corresponding differential feature of the pattern displayed by Sensitization group was its tendency to be more responsive in blood volume. Both the noninformed groups (NI and SE) were prone to have more respiratory disturbances, less frontal and orbicularis oris decrease and larger

Table 7. Summary of discrimination analysis of the S2-activity with group-contrasts

F statistics and significances between pairs of groups after step 12 (each F statistics has 12 and 465 dfs; *** p <.000)

Group	NI	PI	FI
Partially informed	13.028***		
Fully Informed	4.850***	6.363***	
Sensitization	22.143***	27.093***	27.945***

Summary of the selection: stepwise entering order and univariate F-to remove values for single variables

Order of entering the variable	F-to remove value of	Lambda	p	Variable
1	32.15	.869	.0000	Frontal EMG decrease
2	28.25	.768	.0000	Blood volume increase
3	14.91	.680	.0000	HR mean change
4	19.84	.616	.0000	FPA constriction
5	19.48	.551	.0000	Blood volume decrease
6	14.89	.499	.0000	Flexor EMG
7	9.39	.470	.0000	Frontal EMG increase
8	8.35	.443	.0000	Respiratory cycle duration
9	10.44	.416	.0000	Heart rate peak change
10	13.98	.393	.0000	Orbicularis EMG decrease
11	9.94	.375	.0000	Orbicularis EMG increase
12	7.29	.357	.0000	Respiratory disturbances
13	5.35	.345	.0000	SCR amplitude

Canonical discriminant functions

Function	Pct of var.	Can. corr.	Wilks´ lambda	Chi-sq	df	p
0			.345	500.32	39	.0000
1	69.76	.706	.688	176.27	24	.0000
2	25.38	.515	.935	31.401	11	.0013
3	4.86	.254				

skin conductance responses than both of the informed groups.

To detail the contrasts between groups further discrimination analyses were computed first with all groups and conditions included. The results reveal that the largest difference is between the least and most informed groups. These also disclose that there is a monotonic relationship between the amount of advance information and centroid values in this first discriminate function (SE -1.7, NI 0.30, PI 0.63 and FI 0.76), which explains about 50 percent of the variance of the dummy-based contrasts between groups. All variables contributed significantly (see Table 7) and explained (with three significant functions: R1 49.8, R2 26.5 and R3 6.5 percent) a total of 82.7 percent of the total logical contrast between the four groups.

The main contributors in the first function, which locates the positive end of the axis towards FI/PI and negative towards SE-group, were frontal (standardized CDF coefficient 0.63 and correlation with CDF 0.37) and orbicularis oris (0.41 and 0.26) muscles′ responsivity, and HR-mean acceleration (0.48 and 0.27), lack of variability in vasomotor (BV) activity (-0.45 and -0.32) and skin conductance changes (-0.27 and -0.21). Thus the groups were contrasted maximally to achieve the highest score in the most informed group and the lowest in Sensitization group by weighting positively voluntary activity (EMGs) and negatively autonomic responsivity (BV, SCR). An exception was HR, whose contribution balanced to the side of voluntary rather than autonomic changes.

Composition and interpretation of the further axes was too complicated to offer a good basis for evaluation of the patterning of S2-activity as a function of information. Descriptive data for this purpose comes from more directly related SWDA-results examined below.

The condition-specific univariate results established that two conditions, shock-UCS and Motor-condition, were especially prone to apply as contexts for a demonstration of an inverse relationship between advance information and ANS-response probability/amplitude. Table 8 shows that in these conditions the mean success of discriminating the critical groups (SE vs. FI and NI vs. FI) was best also in condition-specific multivariate evaluations. This difference is especially clear in contrasts computed between NI- and FI-groups.

In sS-condition the variables contributing in the largest contrast were autonomic while especially in cognitive conditions they were mainly somatic. The contribution of ANS-variables appears also in Motor condition in NI/FI-contrast. The three largest standardized CDF coefficients and correlations of variables with CDF were in the autonomic variables (SCR, respiratory disturbances, HR and blood volume) in both of these conditions and group-contrasts with only two exceptions. These were the 2. largest correlation of orbicularis oris decrease in FI/NI: shock-Stimulus comparison and the 3. largest correlation of the same variable in FI/SE: Motor condition comparison. Some tendency to the same direction could be found in the response pattern elicited by the tone-Stimulus especially in FI/NI-contrast

Table 8. S2-related contrasts between Fully Informed and either Noninformed or Sensitization groups. All variables were included in analyses and results are summarized for each condition separately.

Condition	Number of variables with >1.0 F-to remove	F-value* after the last step	Canonical correlation	Percentage of correct classification
Fully Informed versus Sensitization group				
Sensory task	9	8.07	84	95.0
Shock-Stimulus	5	13.73	82	97.5
Arithmetic task	6	10.30	81	95.0
Memory task	7	11.73	85	97.5
Motor task	9	10.07	87	97.5
Tone-Stimulus	7	8.60	81	92.5
Fully Informed versus Noninformed group				
Sensory task	5	5.16	66	77.5
Shock-Stimulus	6	8.81	78	90.0
Arithmetic task	2	2.62	48	65.0
Memory task	3	3.13	56	80.0
Motor task	6	6.24	73	87.5
Tone-Stimulus	6	3.82	73	92.5

* The number of entered variables (second column) is the numerator and N (=40) minus this number minus 1 is the denominator of the df-values for the F-value.

(only the 2. largest correlation of flexor EMG was an exception). In cognitive conditions the main contribution to group contrast resulted from EMG-variables. Also the largest correlations of CDF were with EMG-variables in these conditions.

As mentioned above in the contrast between FI- and SE-group an unexpected relationship between response amplitudes and advance information was visible in some conditions. This same effect manifests itself also in the multivariate evaluation. It appears especially in the lesser EMG-activity in Sensitization group. This occurred especially in conditions presupposing effort (viz. in cognitive and Motor conditions). Sensitization group also tended to respond less with heart rate in the tasks presupposing cognitive performance (Ar, Me and Sc). This resulted in a patterning of lower HR-acceleration with lesser frontal and flexor EMG-increase in responses of the

SE-group in these conditions. A possible reason for this difference would be that this group applied less effort, was less involved in the task performance. This can be interpreted to follow from the less organized (randomly ordered) and thus less motivating presentation of the events in SE-group. This interpretation is supported also by the interview data collected immediately after the experimental runs.

3.3.7. The 'preception-pattern'

Shock-Stimulus-condition was taken for further examination because of its special relevance as a context for demonstration of the preception effect. Discrimination analyses were first performed for contrasting the two less informed groups concomitantly against Fully Informed group.

Contrast between these needed, to be successful, two discriminate functions. The first function accounted for 63 % (multiple r 0.79) and the second for 41 % (r 0.64) of the variance included in the dummy-based contrasts between these three groups. When the function coefficients were varimax-rotated to have maximal separation between the groups as the basis for calculation of the contribution of variables, the first function achieved a position in which SE- and FI-groups were maximally discriminated (group centroids had the values NI=-0.45, SE=1.70 and FI=-1.25). In the second function NI- and FI-groups had the farthest centroid values from each other (NI=1.06, SE=-0.05 and FI=-1.12). The variance of the data had thus the property of discriminating effectively both of the noninformed groups from Fully Informed group but this presupposed two separate discriminant functions.

In line with the earlier results relating to the preception hypothesis, skin conductance rose to become the most consistent contributor in the explanation of the contrast between both of the less informed groups and Fully Informed group. The contribution of respiratory disturbances was, however, even more pronounced in contrasting NI and FI. The standardized CDF-coefficients were 0.44 and 0.32 for SCR and respiratory disturbances, respectively, in the first function, and 0.24 and 0.72 for the second, which together with consistent correlations with CDF (0.29 and 0.23 for SCR and 0.32 and 0.51 for respiratory disturbances) verify this contention. Respiratory disturbances and SCR had a central and independent role.

On the basis of SWDAs computed separately for contrasting these two pairs of groups (FI vs. NI and FI vs. SE) a more detailed picture of their

Table 9. Summary of discrimination analysis contrasting Fully Informed and the two noniformed groups with S2-scores of shock-Stimulus condition

Con-trast	F-value	Multiple correl.	The correlations of variables with the CDF (six largest)						Correct classifications
NI/FI	8.81*	.78	Rdis	orEMGd	SCR	FPA	HRm	BVd	90.0 %
			.61	-.39	.37	-.20	-.20	.19	
SE/FI	13.73	.82	BVd	Rdis	SCR	BVc	frEMGd	orEMGd	98.5 %
			.56	.42	.33	.24	-.20	-.17	

* Six variables contributed significantly in the first and five in the second contrast. Therefore degrees of freedom are 6/33 and 5/34, respectively, for the contrast-Fs.

differences could be shaped. A summary of results from these analyses is presented in Table 9.

The same variables achieving a visible contribution in the above more global analyses also have it here. The most remarkable difference from the univariate results is in the role of frontal EMG. It seems to reflect tautological variance with the other measures and therefore its contribution fades out in a stepwise procedure. Furthermore the blood volume variability (both constriction and dilation) seem to be sensitive to reflect the variance which contrasts maximally the Sensitization group with Fully Informed group. Inspection of the standardized CDF coefficients reveals that about the same variables as displayed in Table 9 as correlates are represented. In the FI/NI-contrasts the HR-peak-change contributes to the direction of NI and HR-mean to the direction of FI-group.

The supposed motivational difference which was interpreted to prevail between SE and the other groups above, although was consistent with the behavioral/psychological and physiological evidence for SE-group being less involved in the tasks, did not seem to affect much the physiological effects of advance information which manifest evidence of negative preception. The patterns contrasting maximally both of these less informed groups with the Fully Informed group were quite similar. And this concerns especially the role of the verifiably negative preception-related variables: skin conductance and respiratory disturbances.

It is possible to conclude that quite consistent changes in psychophysiological response patterns result from the exposing of human subject to different kinds of experiences or performances without sufficient advance information of the event. When the exact time (temporal certainty) and/or content of the event (event certainty) were varied, especially those variables which are often thought to reflect emotional arousal (SCR and respiratory disturbances), showed larger changes to the critical event the less certain Ss could be about it. If the onset-time but not the quality of the event was predictable the difference from full predictability was less pronounced but highly significant. The statistical prediction was also in this latter case so successful that none of the members of FI-group was misclassified by the classification procedure of SWDA. Four of the members of Noninformed groups were classified to belong rather to FI-group. This number matches quite well the percentage of Ss showing above-chance prediction (ie. right strategy of prediction) of sS-conditions as far as specific preparatory responses eg. in skin conductance and respiratory variables and Ss´s subjective, postexperimental accounts of their prediction behavior during the experiment can be used as its criteria.

3.4. Task performance and subjective ratings of the experimental events

Task performance and its relation to physiological responses was evaluated by means of performance scores for each task and the correlations between them and the relevant physiological variables. The variables and their corresponding tasks were as follows: the number of correctly memorized items in Memory condition, the number of right answers in Arithmetic tasks and the reaction (RT) and performance (PT) times in the Motor-task. The ratings concerning the unpleasantness and the difficulty of conditions were used for group-comparisons. These were also correlated with the physiological variables.

3.4.1. Differences between groups

There were some differences in the cognitive performances between the groups. The means of memory recall scores did not differ except in one (3.) task: Fully Informed group achieved a significantly better mean score ($p < .02$). In the performance of Arithmetic task the means ordered as a function of advance information (FI>PI>NI>SE), but the differences failed to achieve significance.

The groups did not differ significantly in the mean reaction time or performance time in Motor task condition.

Only a few between-group differences were found in the ratings. No significant difference was found in the rated difficulty of the cognitive tasks. However, both the tone-Stimulus and Motor task were rated as more ´difficult´ in Sensitization group than in the others (p <.04 and <.02, respectively). Sensitization group tended to rate the loud tone also as more unpleasant (p <.04).

3.4.2. Differences between conditions

The rated difficulty of the tasks differed markedly (p <.000). The means were 2.3 for Arithmetic task, 1.7 for Memory, 1.0 for Sensory and 0.56 for Motor tasks.

Similarly there were significant differences (p <.000) in the experienced unpleasantness of the conditions. The respective means were 1.8 for the shock, 1.3 for the tone, 1.0 for the mental Arithmetics, 0.89 for Motor tasks, 0.55 for Memory and 0.29 for Sensory discrimination tasks.

3.4.3. Correlations between performance and physiological variables

Correlations between the performance scores and the physiological measures revealed significant covariation between these two spheres of activity as can be seen in Tables 13-14 of Appendix 2.

Several physiological measures correlated significantly with the RT- and PT-scores. High correlations were found between the heart rate acceleration during the pre-S2 interval and both of these scores in FI group. The first-interval peak increase from the pre-trial level of heart rate had the highest positive correlation with the time needed for successful responses (0.48, p <.001 and 0.51, p <.001, respectively, for RT and PT). Also the mean HR-changes correlated significanty. The highest correlation was between the second-interval mean (HRm2) and pressure time (PT; r 0.56, p <.03) Also the vasodilation correlated, especially during the first interval, very significantly with RT (r -0.72, p <.000). Additionally the pre-S2 scores of EMG-activity in orbicularis and frontal area, ie. in the irrelevant muscles but not in the flexor, had consistent positive correlations with the response time scores. The highest correlation was between first-interval orbicularis response and PT (0.75, p <.002), but all related EMG increase-scores had at least 0.30 correlation with both RT- and PT-scores. During the second interval also the frontal decrease measures correlated highly (r -0.62 and -.57, respectively) with PT and RT.

A multivariate evaluation with step-wise regression analysis proved that the first two (HR and pulse amplitude) variables together explained 63 % of the variance of the reaction time in Fully Informed group and that with some additional variables, viz. the respiratory cycle duration (which singly did not correlate at all) together with these EMG measures, the percentage was raised to 81. Entering these variables in this order boosted the prediction value in every step significantly. It is worth notice that already the first-interval response scores were predictive with respect to RT-performance in FI-group.

Only the heart rate increase from the pre-trial level predicted significantly the RT in Noninformed group. Other variables did not add significantly to the contribution of predictor variables in a stepwise multiple regression analysis.

Memory performance correlated significantly with the EMGs of the head area. In Fully Informed group the correlations of the orbicularis and the frontal second- and third-interval increases were consistently negative and varied between -0.36 and -0.63, the latter being with the third-interval orbicularis variable. In the other groups no significant correlations were found in these variables. Thus it seems that the preparation opportunity for memory performance may affect an arousal-performance relationship found in this cognitive task. The group difference was not only ´technical´ in the sense that variances would be different. The means, however, as stated above, were higher in FI-groups, especially in the orbicularis. Performance was more successful in Ss who were in a position to prepare, but who exhibited less EMG increase in the speech area.

The only systematic performance-arousal correlation in the Arithmetic task was the correlation between performance level and frontal activity increase during the task activity. The coefficient was highest in FI-group (r 0.31, p <.11) and statistically significant only in the total number of Ss (r 0.24, p <.02).

3.4.4. Correlations between difficulty-ratings and physiological variables

The correlations between the physiological changes and the ratings of difficulty and unpleasantness were computed over all conditions in order to find the general covariance between these two domains. Table 15 in Appendix 2 summarizes the coefficients and p-values. Statistically significant correlations were found between the difficulty and the heart rate mean score during first and third intervals (correlations for each 1-3 interval were 0.22, 0.13 and 0.30, respectively) in Fully Informed group. Similarly orbicularis oris EMG-increase and difficulty rating were in consistent positive relations to each other. The highest correlations were found, however, with the probability of orbicularis EMG decrease-variable. Correlations were -0.24, -0.25 and -0.24 for the three consequent intervals. The third variable which correlated significantly already during the pre-S2 interval in Fully Informed group was blood volume amplitude. Its dilation covaried significantly with the difficulty rating so that the highest r was found with the third interval constriction-score (-0.31, p <.000). The pre-S2 dilation score had a r of 0.21 (p <.01).

The third-interval scores of almost all variables (except respiratory cycle duration) correlated significantly with the difficulty rating in the total group. In blood volume constriction and skin conductance the correlations were negative, and in all other variables positive with respect to activity increase.

In some variables the arousal-difficulty correlation was affected by the advance information. Thus the correlations failed to differ from zero in the third-interval data of Fully Informed group in respiratory disturbances and frontal EMG, although were significant in other groups.

3.4.5. Correlations between unpleasantness-ratings and physiological variables

The rated unpleasantness of the S2-events also formed several significant relationships with the physiological reactions to the tasks and stimuli. Also some pre-S2 changes in Fully Informed group correlated with the experienced unpleasantness of the expected events. These last correlations were, however, significant in the condition-specific analyses only.

An unexpected correlation was found in frontal activity. In shock-Stimulus condition it displayed the less increase the more unpleasant the shock was rated. Correlations with the probability of frontal EMG increase were -0.55 (p <.009) during the first interval and -0.63 (p <.002) during the second interval. The respective correlations with the decrease variable were 0.40 (p <.05) and 0.63 (p <.003). In mental Arithmetic condition the anticipatory skin conductance responses, and especially the first-interval amplitude correlated highly with the rated unpleasantness (r 0.59, p <.005 and r 0.29, p <.12, respectively for first- and second-interval scores).

Correlations computed across the conditions and the groups with the third-interval data revealed some highly significant values. Thus skin conductance correlated with a r of 0.18 (p <.000) and frontal EMG decrease with a r of 0.13 (p <.006) and blood volume constriction with a r of 0.13 (p <.000) with the unpleasantness rating. The unpleasantness-skin conductance correlation results mainly from the two UCS-conditions; that of frontal EMG decrease from Motor and the UCS-conditions. Motor, shock and Arithmetic conditions exhibited this pattern in the within-condition correlations with blood volume responses.

4. GENERAL SUMMARY OF RESULTS

4.1. Fractionation of ANS- and SNS-patterns according to event-specific demands

The general purpose of the present study was to prove the demand-specificity of physiological arousal by showing that different events produce qualitatively different ANS-SNS response patterns. The results quite consistently verify the division of ´arousal´ into several qualitatively separable types depending on the condition in which the physiological responses were produced. Although almost all multivariate contrasts between response patterns produced by the six critical events were statistically significant, the three main types of events, viz. 1) motor, 2) cognitive and 3) sensory (stimulus) ones were accompanied by qualitatively distinct patterns clearly separable from each other.

Motor condition produced skin conductance responses, pulse amplitude constriction, heart rate acceleration and naturally also flexor EMG increases. All but heart rate changes were consistently present also in the anticipatory responses for motor activity. The multivariate pattern significantly contributing in differentiating the Motor condition from the others included, in addition to these variables, also blood volume constriction.

The multivariate compounding of the pre-S2 responses in the FI-group revealed that skin conductance made a dominant contribution (surpassing eg. flexor EMG and HR-peak acceleration) to distinguishing Motor and Cognitive conditions. Finger pulse amplitude constriction and EMG-increases in the three measurement locations differentiated Motor and Stimulus conditions during anticipation. The measures of HR fractionated so that in contrast to the slower change appearing in the increase of the mean HR (of the interval) typical to cognitive conditions, the motor pattern was characterized by peak acceleration and, in contrast to that to Stimulus conditions, by mean acceleration. The role of flexor EMG increased in the pattern of the second pre-S2 interval so that it explained largest part of the differential variance between Motor and other conditions.

The results consistently show that motor demands elicit a characteristic physiological pattern which is about the same during anticipation and execution. In the total ANS-SNS pattern, skin conductance and vasoconstriction as well as HR acceleration are most centrally represented in addition to directly motor (flexor EMG) activity. The latter is obvious during execution but it appears, covertly, also during the pre-S2 intervals.

The ´cognitive processing demands´ were represented in the present study by Arithmetic and Memory tasks and partially also by Sensory discrimination task. All three tasks were accompanied by distinct respiratory characteristics (more stable, less disturbed cycles), Arithmetic and/or Memory tasks also by heart rate and orbicularis oris EMG increases, pulse amplitude constriction and skin conductance responses. From these variables heart rate and orbicularis oris EMG consistently increased even during preparation and there was additionally a tendency for skin conductance responses to increase during the second pre-S2 interval in the Arithmetic condition.

Multivariate evaluation revealed that the physiological response patterns accompanying the cognitive conditions were most strongly contrasted by those of Stimulus conditions. In this contrast, the HR showed the most critically different changes, but independent contributions came also from the other variables mentioned above. Also the pattern characterizing Motor condition was significantly differentiated from that sensitive to cognitive demands. Thus HR mean- (not the peak-) acceleration and orbicularis oris EMG increase were more typical and skin conductance responsivity less typical to preparation for cognitive than for motor activity.

It can be summarized that cognitive activity, as represented by Arithmetic and Memory tasks, elicits a characteristic pattern of physiological changes. Compounds of concomitant HR and orbicularis oris EMG increase differentiate this cognitive activity both during anticipation and execution from the other conditions of the present study. Sensory discrimination task could be differentiated from Motor and shock-Stimulus conditions both during anticipation and execution but otherwise the pattern accompanying this condition represented a mixture of that typical to cognitive and Stimulus (especially tone-Stimulus) conditions.

There were two Stimulus conditions; in one the shock-Stimuli served as S2, in the other the tone-stimuli. Univariately only respiratory duration and orbicularis EMG achieved a significant contrast between both of these two and task-conditions. Shock-stimulus was, however, more clearly discriminable on the basis of the responses it elicited. It was typically followed by skin conductance response, flexor EMG increase and blood-volume constriction but was probably too mild to be preceded by anticipatory changes in all these measures. The only single variable responding reliably in anticipation to the shock was skin conductance.

On the other hand the multivariate pattern clearly contrasted the Stimulus conditions from others both on the basis of pre- and post-S2 data. In the SWDA-results the canonical discriminant functions typically contrasting Stimulus conditions from all the other conditions formed the second function, although often the first function differentiated these conditions (or sS) from one of the other two condition types. The characteristic variable compounds discriminating Stimulus conditions from the others were HR mean and EMGs, especially orbicularis oris; both showed typically less change in Stimulus conditions.

Overall, it can be summarized that also Stimulus conditions tended to elicit, and be anticipated with, a differentiable pattern. However, the homogeneity between the two Stimulus conditions was not much higher than that between eg. tone-Stimulus and Sensory task conditions. Shock- and tone-Stimuli elicited and were preceded by somewhat different patterns. However, the mean F-values describing this contrast were clearly lower than the mean F-values in contrasts between shock- and conditions other than tone-Stimulus.

All the afore-presented establishes that at least three different ´arousals´ can be empirically differentiated, each characterizing responses to differentiable demands.

4.2. Anticipatory arousal

To verify that this event-specificity in the phasic physiological responsivity is demand-specific also in the sense of having manifestations already in the pre-event arousal when the event is predictable, the study purported to test the hypothesis that this specificity increases in the pre-event patterns as a function of available advance information.

Anticipatory patterns of the four differentially informed experimental groups were compared to test this hypothesis. The multivariate evaluation based on the ability of a discrimination analysis to statistically contrast the pre-S2 patterns according to the S2 event in the four groups offered an unequivocal answer. All the SWDA parameters quite consistently established that the discrimination success was a function of the amount of advance information. A further inspection of the results reveals that explicit information added by the experience of the paired presentation of S1 and S2 clearly produced the most specific anticipatory pattern. The information (via a label or cue) as such was not sufficient for clearly specific anticipatory responses. This was shown by the results from those subjects who experienced unpaired labels. Also the results from an additional control group, which experienced only the label slides without being instructed to perform the tasks or without experiencing the stimuli, were compatible with this conclusion.

On the other hand the information sufficient for production of event-specific anticipatory arousal pattern before the critical event need not be given in explicit labels; it seems to be enough that the Ss have a cue, an interpretable code. This was evidenced by the fact that such a code served to produce specific patterns in the second pre-S2 interval in Partially Informed group, although clearly less reliably than in Fully Informed group. Thus regardless of how the information was acquired, it resulted in an autonomic-somatic preparatory pattern specific to this event provided that the subject had found out that it at the same time is a signal of an immediate delivery of the informed event.

All variables seem to be not equally sensitive to display specific autonomic-somatic preactivity. The present results suggest that this sensitivity is more probable the more responsive the variable in question is to the event itself.

4.3. Relation between pre- and post-S2 responses

To characterize the nature of the pre-event specificity it was hypothetized that it models the response elicited by the critical event itself. The univariate results revealed that only in a few cases were the statistical contrasts between the conditions different during these two intervals. In all the main variables representing each arousal type, as classified above, this correlation was clear: skin conductance was most sensitive to reflect motor demands and Motor condition was contrasted with the others during both pre- and post-S2 intervals. SCR's additional sensitivity to respond to shock-Stimulus resulted also in similar heightening of responses during the preparatory interval. An exception with SCR was its tendency to increase in anticipation of Arithmetic task in FI-group, although the performance itself was not consistently accompanied by as large SCRs. The discrepancy was only relative, as can be seen by comparing Figures 2B and 2C.

Inspection of the plottings of FPA-profiles (Figs. 4A and B) makes clear the resemblance between the pre- and post-S2-patterns in the FI-group. HR, which was most sensitive to cognitive demands, displayed it during both preparation and execution (as illustrated in Fig. 5). Similarly, lack of increase in HR and EMG measures in Stimulus conditions was shared by the two intervals compared. The resemblance between the pre-and post-S2 response was apparent throughout the data and because this covariance only occurred in FI-group it cannot be explained by referring to the effect of mere temporal proximity of the compared scores.

4.4. Anticipation and orientation

A further interest in the present thesis was the effect of advance information on the immediate versus later physiological changes in the early and the late parts of the pre-event interval. Following the usage of conditioning research to consider the immediate response to S1 as a potential representative of an orienting response and the later pre-S2 activity as an anticipation response, the first was expected to show more non-specificity and habituation as a function of trial repetition and the latter more specificity and increase rather than diminution.

The results did not provide any unequivocal support for such a differentiation. Both parts of the pre-S2 period manifested clear specificity in the Fully Informed group. It seems that to the degree Ss have free resources to specifically prepare for the future event which they realistically expect, this preparation manifests itself immediately after the receipt of the information in peripheral physiological changes. This ´resource-relatedness´ is supported by the difference found between Partially and Fully Informed groups. The first had to decipher the code in S1 to achieve anticipatory information and this occupied cognitive resources for some seconds and made the immediate response less specific with respect to S2. In Fully Informed group, this information was explicit and could thus be instantaneously used which resulted in an immediate physiological response specificity during the early part of the interval and continued during the late part of the period preceding S2.

The habituation evidence from the present data, however, introduced support for the contention that some orientation-type effect might have been mixed into the response patterns. Thus in three variables, skin conductance, heart rate, and pulse amplitude, the immediate responses to S1 revealed more decrease (habituation) than the pre-S2 responses. Skin conductance and HR disclosed the same tendency also in the reduction of the tonic levels as a function of trials. Thus in those variables, mostly used as measures of the orienting response, the two effects, the nonspecific forms of orienting reflex and the specific anticipatory activity appeared concomitantly, and clearly enough to be statistically verified in the pre-S2 physiological responses.

4.5. Advance information and physiological changes

The further aim of the experiment was to characterize the effects of advance information on the response patterns produced by the critical (S2) events. These effects can be examined in two ways: generally by comparing the response patterns produced by the critical events in the differentially informed groups and specifically to test the hypothesis based on Lykken´s preception-theory. The results concerning the first point indicate that the effects are fractionated and can be said to have ´tonic´ and ´phasic´ consequences. Sensitization group faced the experimental conditions differently because of experiencing the S1 and S2 in an unpaired order. Both the post-experimental interview data and physiological changes are consistent with the interpretation that this might be a result of an attenuated involvement in the experimental events in this group. This is also compatible with the lower performance means in condition requiring effort like in Arithmetic and Memory tasks, although this difference was not clear enough for reaching significance.

In the area of central interest in the present work, the physiological changes, these main effects were further fractionated between active ie. task- and passive ie. stimulus-events so that in the former case diminution of executive ´arousal´ (in SE) and in the latter case an increase of elicited responses to tone and shock-S2 was evident in the less informed groups. Comparison of the S2-responses between the Fully Informed and Sensitization groups during cognitive and Motor conditions quite consistently revealed larger HR accelerations and orbicularis oris increases in the first. A similar difference was apparent also in comparing Partially Informed and Sensitization groups, and also, although less unambigiously, between

Noninformed and Sensitization groups.

The clearly longer cycle duration in respiration in SE during all the conditions is also consistent with the above motivational interpretation as is the tendency of Sensitization group's skin-conductance level to be lower during the experiment. But the latter did not quite achieve significance and there were also variables in which higher rather than lower tonic levels characterized this group. Thus the HR mean of the pre-S2 measurements was five beats higher in SE than the respective mean of the other groups (76.8 vs. 71.8 bpm). This makes it difficult to account for the difference via tonic 'arousal'. Rather the difference seems to be restricted to the voluntary effort, which very probably was less in Sensitization group. As a manifestation of such a specific arousal difference, this group disclosed a less pronounced tendency to respond with EMG, ie. with 'voluntary' responses, in the active conditions.

4.6. Advance information and preception effect

On the other hand, the between-group comparison with the data from the passive, ie. tone-Stimulus and especially shock-Stimulus, conditions revealed that Sensitization group, like Noninformed group, was more responsive with the typical preception-variable, viz. skin conductance response and also with respiration.

These differences cannot be explained in terms of motivational, tonic orientation to the tasks. These differences rather reflect differences in the organism's preparedness to the input, the orienting reflex to new, unexpected stimulation when there is no advance information. It appeared most clearly in the contrasts between Noninformed and Fully Informed groups. Thus Noninformed (and also Sensitization) group responded with more frequent respiratory disturbances and skin-conductance responses to all sudden stimuli events to the shock- and tone-Stimulus and also to the imperative stimulus for the motor response.

The multivariate results established that all those effects were quite independent: variable compounds together explained a significantly larger part of the between-group differences than the single variables. This means that the 'preception' effect cannot be explained eg. as a mere result of respiratory disturbances; rather the latter are independent members of the physiological changes related to preception effect in addition to the skin-conductance effects which are frequently encountered in earlier research.

5. DISCUSSION

5.1. Arousal

The physiological responses accompanying the S2-event of the present study represent activity which has been studied in terms of ´arousal´ or ´activation´ in psychophysiology. In this chapter related findings of earlier literature are compared with the present results.

The first proponent of the ´activation´ concept, Elizabeth Duffy (1957, 1972) defines it as a phenomenon which is quantifiable via physiological indices like skin resistance, muscle tension and cardiovascular measures. She furthermore stresses that activation or arousal should be indicated with a combination of several measures. Most research has, however, been comprised of only one or at best two physiological variables. Thus not much is known about multivariate patterning of arousal. When simultaneous measurements have been made the findings have often led to suggestions of a multidimensional nature of arousal or of fractionation of the resulting pattern.

5.1.1. Fractionations of arousal: Heart rate vs. skin conductance and vasomotor responses

The most explicit theoretical account of the fractionation of physiological ´arousal´ has its origin in the concept of response stereotypy (Lacey, Bateman, & VanLehn, 1953). There is some evidence of the tendency of ANS-responses to pattern according to situational demands. Therefore eg. Lacey (1958) is ready to speak about situational stereotypy or specificity. The best documented conceptualization of situational stereotypy associates separate ANS-patterns with two ´attentional modes´, viz. ´intake´ and ´rejection´ of environment as proposed by Lacey, Kagan, Lacey and Moss (1963). They showed that such modes tend to be accompanied by heart rate acceleration and deceleration, respectively, while skin conductance increases in both cases. There is not much controversy about the empirical correlation that accelerated HR accompanies such cognitive activities which are performed most effectively when external stimulation is excluded from attention (rejection-mode). Some ´intake´ situations, like anticipation of the imperative signal in a RT-task, are very typically accompanied by heart rate decrease as shown eg. in the review by Lacey and Lacey (1980).

Electrodermal activity has also quite consistently been shown to increase during both types of attention (Lacey & Lacey, 1970 and eg. Tursky, Schwartz, & Crider, 1970; Ikonen & Lyytinen, 1972). Both of these conditions have also been reported to produce vasoconstriction. For instance Williams et al., (1975) demonstrated finger pulse amplitude constrictions during both information intake (eg. reading of blurred words) and mental arithmetic. Thus heart rate has been shown to exhibit two specific forms of ´arousal´ in relation to attentional demands, while electrodermal and vasoconstrictive responses seem to be less specific.

The present data are consistent with the Lacey´s distinction in that heart rate consistently increased during cognitive effort and was much less accelerative when Ss performed Sensory tasks or experienced sensory stimulation (sS,tS). In its original form the Lacey´s theory also proposes that other ´rejection´ situations, like noxious stimulations, produce the same pattern. In the present study, as also in other relevant (eg. Zeaman & Smith, 1965; Deane, 1969) research, exposure to the aversive stimulation has not been so unequivocally accompanied by heart rate increase.

In the present study heart rate did not increase either as a response to tone or to shock-Stimuli. At least the latter represents an aversive stimulus meant by the Laceys to have the critical feature of provoking a ´rejection´ mode of attention and should have been accompanied by an accelerative pattern. The subjective ratings revealed both of them to be more unpleasant than the other conditions, which can be taken as support of their ´rejection´ value. This is a clearly deviant result with respect to the Lacey´s account. At the same time it is, however, consistent with the balance of relevant empirical evidence as it stands today (Bohlin & Kjellberg 1980).

Blood volume tended to display opposite changes in the two rejection conditions: to decrease during Arithmetic task and to constrict in response to shock. Skin conductance increased both to shock and during mental arithmetics. Pulse amplitude tended to constrict concomitantly with SCRs. Skin conductance did not, however, respond to cognitive effort as consistently as it did to shock-Stimuli. The case with pulse amplitude was the opposite.

The SCR´s higher sensitivity to respond to aversive than cognitive events is compatible with the contention of Fowles (1980) and the results of Cacioppo and Sandman (1978) that electrodermal arousal is more sensitive to behavioral inhibition or affection-laden strain than to behavioral activation and cognitive, information processing demands. In the case of heart rate, present results revealed an opposite kind of sensitivity. This also parallels the findings of the above authors, namely that HR is more sensitive to reflect behavioral activation. In all, these last findings together offer an interesting addition to the discussion about further ´fractionations´.

The physiological response pattern recorded during the sensory discrimination task did not clearly categorize into either of the two Laceyan patterns irrespective of its intended role in our procedure as an unambiguous representant of the ´intake´ mode. This condition produced the lowest skin conductance responses and no clear decelerative change in heart rate. The accelerative changes were, however, smaller than those found in Arithmetic or Memory task conditions.

To understand this apparent discrepancy, a short review of the evidence on which the Lacey´s hypothesis is based is appropriate. It has its origin in data from conditions of environmental intake in which tonic heart rate level rather than any phasic change has been the main measure (Lacey et al., 1963). The intake situations have consisted eg. of noises, flashing lights or other auditory or visual stimulation or tasks in which some discrimination within the given sensory input should be made (eg. finding hidden faces in drawings in the Obrist´s (1963) replication of the Lacey´s studies). The scores used in these studies of Lacey and in further replications consisted of means of activity over tens of seconds. Mostly these were based on differences in the mean level of the intake period from the so called alerting period (a period at the beginning of which Ss were warned about a future stimulus and were ´anticipating´ it). An examination of the present data from this point of view means that the predicted pattern of difference scores can be found: the mean of HR prevailing during the third interval (intake) was relatively lower than that of the first and second intervals during Sensory condition but higher during Cognitive conditions. Similarly skin conductance increased and pulse amplitude constricted from the ´anticipatory´, second-interval level to the third in all those conditions.

Later some studies have been published which have used both phasic measures and a similar intake condition to the one that is used in the present study. These concur consistently with our findings that as soon as the sensory task presupposes intake which requires active mental operations like imprinting of the sensory input on the mind (encoding a visual input for recognizing it later eg. from embedded figures, a procedure used by McCanne and Hathaway, 1979) or making a discrimination between at least two objects given concomitantly as an input (as in the present data) the resulting phasic heart rate change is accelerative rather than decelerative with respect to the pretrial-level.

But explicit heart rate decreases can be demonstrated and a relevant stimulus for producing them may even be one which has been typically categorized as a stimulus which provokes environmental rejection rather than intake, viz. shock. In the present data shock-Stimulus was followed by a heart rate that was lower than the one accompanying the onset of Sensory task. The result is the same regardless of the scoring method (see Fig. 6). Thus shock- and tone conditions displayed a pattern more like the traditional ´intake´ response than did the Sensory task, which, however, required attentive intake of environment.

5.1.2. Contributions of single measures

Many of the measures made specific contributions which could not be immediately identified as consistent members of response patterning. The single contributions are therefore discussed separately.

5.1.2.1. Respiration

As far as I know there is no detailed empirical evidence available about the relations of the two Laceyan attentional conditions and respiratory changes. Lacey (1980) has recently written in passing (without mentioning any evidence) that respiratory variables do not behave differently during those two classes of behavior. Similarly, related studies of Porges and Raskin (1969) and Walter and Porges (1976) did not reveal consistent evidence for the correlation of attentional requirements and respiration. Coles (1972) has reported that change from alert expectation to discrimination task is accompanied by shortening of the respiratory period which tends to accentuate as a function of the time the task-performance requires.

The present data included two separate scores of respiration. The first, respiratory disturbances, tended to have a lower probability of occurring during tasks presupposing cognitive effort than during other conditions. The second variable, respiratory cycle duration, revealed a between-condition difference so that the two stimulus conditions were accompanied by slower respiratory cycles than the conditions presupposing active participation from the subjects. The mean respiration was both more regular and faster during cognitive tasks (including the sensory-cognitive task) than during the other conditions. This pattern was consistent in the three less informed groups. This lends some support to a preliminary hypothesis that some ´fractionation´ between these two attentional modes may appear also in the respiratory dynamics.

5.1.2.2. Electromyographic activity

We and others have previously presented data (Lyytinen et al., 1977; Ahonen et al., 1977; Sokolov, 1972; Cacioppo & Petty, 1979a, 1979b) which support the specific sensitivity of orbicularis oris activity to variations in cognitive effort. The present findings also display more location-specific EMG activity during cognitive tasks than as a response to shock or tone-Stimuli.

The results did not reveal any general tension factors, thus conforming to Davis´ (1957) statement that there are many different tension states. Also the data reported to support a general tension factor reveal that head muscles tend to be unrelated to it and specifically affected during cognitive activity (Goldstein, 1972). An even more specific pattern was visible in the present data. Cognitive tasks, especially Memory task, were accompanied by an increase in orbicularis oris response probability. Neither frontal nor flexor activity displayed a similar contrast with other conditions. This result does not easily match with any arousal theory. Rather, it parallels such a version of the motor theory of mind which assumes that the peripheral motor activity may, via some kind of feedtrough of neuromuscular loops between brain and speech musculature, have some supporting role in cognitive activity (Jacobson, 1973; A. Sokolov, 1972; McGuigan, 1978).

Alternatively such an activity may represent only an efferent overflow from the activated brain processes, whose index speech organ EMG thus could be. It may also be that this particular EMG activity is even more specific, manifesting only such an ´overflow´ which has been shown to accompany active subvocal rehearsal (Locke & Fehr, 1970). Speech-organ EMG has been demonstrated to be often present especially in children during memorization and reading tasks (Garrity, 1977). The present findings appear to be most compatible with this last interpretation. The most pronounced activity was found during Memory task which might include such rehearsal activity.

The ´overflow´ interpretation is also in agreement with the observed correlations of orbicularis EMG with the memory performance level and difficulty rating. The performance tended to be more successful the less EMG-activity accompanied it. It may be expected that those who have difficulties with Memory tasks resorted more to the ´inner´ speech ´strategy´ during rehearsal. It is probably used more the less automatized the needed processing is. In a well practiced performance it may rather represent a needless overflow and should fade out as a function of skill development as speculated earlier by Pribram (1975), Lyytinen (1976), Ahonen, Lyytinen, Partanen and Pietiläinen (1977). The observed significant positive correlation between the difficulty rating and orbicularis EMG activity during the tasks is consistent with the above interpretation. Accordingly the ´overflow´ in the present context might have first of all reflected a lower skill level.

There were differences between groups in orbicularis oris responsivity specifically to Memory task. Only Fully Informed and Noninformed groups consistently showed this tendency. The most apparent explanations is that 1) Partially Informed group was too much involved in the code deciphering task not to respond with equal proportion to S2-specific arousal and 2) Sensitization group was not sufficiently involved in the task activity to manifest equal specificity. Ss of these groups had no possibility to become equally ´set´ for the required performance.

The present findings do not parallel our earlier finding. These made us conclude that orbicularis oris EMG may be more a specific accompaniment of efforts spent on execution of a cognitive task than are the autonomic measures like skin conductance or heart rate which are indices of presumably more general arousal. Although the covariation between these autonomic variables and orbicularis oris EMG was meager in the present study, it was more pronounced especially with heart rate than could be expected on the basis of these previous findings (Lyytinen et al., 1977; Ahonen et al., 1977). In these studies cognitive effort was varied more specifically by presenting Raven tasks of different difficulty for comparison. This difficulty-variable was shown to be more sensitively reflected in differences of orbicularis oris activity than in ANS. The present variation consisted mainly of a qualitative variation between conditions. However, the two Cognitive conditions (Arithmetic and Memory tasks) were rated by subjects to be differentially difficult (respective means were 2.3 and 1.7) and in this case the autonomic measures (SCR,FPA and HR) all had higher means in the mental Arithmetic than in Memory task. In fact EMG showed an opposite difference. Thus more probably the specific demand for memorization (or rehearsal) rather than cognitive effort in general was responsible for this arousal pattern.

These findings are, however, not necessarily inconsistent. As shown, the difficulty effect may appear within a specific task sensitively in the orbicularis activity, but this variation may at the same time be overwhelmed by task-specific qualitative features, like those resulting from rehearsal or ′inner speech′ needed for memorization. This phenomenon appears in the orbicularis EMG in this specific task while it, as well as autonomic indices, may also have some more general role in reflecting cognitive effort at the same time. Compatible with this speculation is the result that heart rate and orbicularis oris EMG together quite accurately differentiated cognitive conditions from the others.

5.1.2.3. Pupillary activity

The existing empirical data tend to support a contention that pupillary diameter is especially sensitive to mental effort or processing load (Hess & Polt, 1964; Stanners et al., 1979; Beatty, 1982). The present findings lend some support to this idea. The performance of Arithmetic and Memory tasks were accompanied by a larger dilation than all others except the performance of Motor task. Consistent with the earlier finding of Kahneman et al., (1969), concomitant increases could be found also in heart rate, and in skin conductance during Arithmetic task. This need not mean that pupillary dilation would reflect merely nonspecific arousal as argued by Nunnally et al., (1967). The present data like that of Stanners et al., (1979) show clearly that pupillary activity is not sensitive to stimulation (like shock), which produces ′nonspecific′ stress as it is reflected in the typical arousal measures in skin conductance and pulse amplitude responses. Thus pupillary dilation can be added to the arsenal of physiological variables which form the cognitive effort-related arousal-pattern. Three measures, viz. heart rate, orbicularis oris and pupillary activity seem to constitute the most prevalent members of that pattern. The first two, which were included in the multivariate analyses, contributed independently in contrasting these conditions with the others.

5.1.2.4. Skin conductance

The sensitivity of skin conductance to change according to motor demands has been demonstrated to appear already while becoming ′set′ to respond motorically (Pugh et al., 1966; Jenning et al., 1971). It can be thought to echo, as already Darrow (1936) pointed out, the biological adequacy of strengthening the grip when a motor response is needed.

Epstein et al., (1975) concluded from their comparative study of sensory and motor determinants of autonomic activity that skin conductance is not specifically sensitive to motor demands. Furthermore they were prepared to state that small motor responses (smaller than 25 % of the maximal squeezing of a dynamometer) do not produce more skin conductance activity than do the mere cognitive effects resulting from the signals used for timing such responses. The present results, as well as a detailed inspection of Epstein′s data, allow no unambiguous agreement with this conclusion. The heart rate response means were, in Epstein′s results, distributed more directly as a function of the squeeze strength than were the skin conductance responses. Both responded reliably also to the smallest motor output (10 %) but only HR differentiated it from the second smallest (25 %). These results were the only basis of their conclusions.

The motor squeeze of 10 kg strength (which is clearly less than 25 % of the maximal) was accompanied here consistently by larger skin conductance responses than even the ′heavy′ cognitive tasks. This is in clear disagreement with Epstein′s conclusion. Skin conductance was more responsive to motor demands than to any other demands included in the repertoire of conditions.

Our result is compatible with evidence collected about biological significance of the electrodermal activity (Edelberg, 1972; 1973). It shows that the adaptive function in manipulative activity is a specifically characteristic feature of the integrated system of neurodermal regulation. The present data do not support Epstein′s contention that the skin conductance activity accompanying the motor response to the imperative stimulus in the reaction time situation could have resulted from mere sensory or cognitive factors included in such a setting.

The second peak in skin conductance′s profile across conditions resulted from shock. This finding is in agreement with the conclusion of Kilpatrick (1972) and the theorization of Fowles (1980) that skin conductance is phasically more responsive to stress-related stimulation than to cognitive or perceptual activity. Less clear is what this stress, more specifically, is. Stimuli may produce electrodermal responses as components of a rather general arousal function mediated by the physical stimulus intensity as argued by Davis, Buchwald and Frankmann (1955). However, the finding that the loud tone elicited so much lower amplitudes than shock-Stimulus is not in agreement with this type of formulation, although comparison of their intensities in physical terms is difficult to quantify and thus makes any related conclusions difficult.

Alternatively, the difference might result from special sensitivity of skin conductance to emotional, threat related factors which are rather a matter of subjective experience. This kind of interpretation of skin conductance responsivity parallels eg. the findings of Niemelä (1969).

Threat-sensitivity should be related to the variable quantified in the present study using ratings of the event's unpleasantness. The correlation between rated unpleasantness of the event and skin conductance was very significant (r 0.18, p <.000). At the same time the corresponding correlation with difficulty rating was significant in the opposite direction (r -0.12, p <.007). These correlations make one further specification possible. Skin conductance seems to be sensitive to increase when the subject is coping with unpleasant events but to be rather 'inhibited' when demands for difficult performance dominate the behavioral activity.

The analogous correlations of heart rate were positive with the difficulty rating (max. r with third-interval acceleration 0.32, p <.000), and did not differ from zero with the unpleasantness rating. The total result parallels nicely the distinction proposed by Fowles (1980) between skin conductance and heart rate. The first is thought to reflect behavioral inhibition (avoidance) and the second behavioral excitation (effort).

In all, the present data quite consistently reveal that motor demands and shock elicit clearly larger skin conductance responses than do other stimuli or cognitive and sensory tasks. However, mental arithmetic also was accompanied by reliable, though smaller, responsivity. This appears especially during anticipation as discussed later. Only the sensory and memory performances seemed almost not at all to be accompanied by electrodermal responses.

5.1.2.5. Pulse amplitude

Although electrodermal and vasoconstrictive activities have independent neural control mechanisms (Edelberg, 1972) these have long been known to show marked covariation (Darrow, 1929). Their activity has recently been proved to follow the course of sympathetic activity measurable in skin nerves (Wallin, 1981) and thus to have a strong common component. Therefore it is not surprising that in the present data, too, this relation was clearly visible. This appeared 1) in the similar ordering of the condition-means, 2) in the correlations between these two measures, which were the highest found between the main physiological variables, and 3) in their compounding in the multivariate condition-contrasts. This last fact points also to the role of some variable-specific contributions which, however, are reflective of common demands.

The motor demands are not the only ones which elicit marked concomitant electrodermal and vasoconstrictive responsivity. If the response amplitudes are ordered across conditions, the moderate responsivity to cognitive effort can be found to characterize both. According to the present results, pulse amplitude may be thought, however, to be relatively more sensitive to reflect cognitive effort whereas skin conductance´s specialty seems to be preferably the responsivity to shock-Stimulus or more generally to stimuli one wants to avoid. Skin conductance correlated positively with unpleasantness ratings and negatively with difficulty, while pulse amplitude constriction exhibited positive correlation with the difficulty ratings (0.10, $p<.025$), which is consistent with this hypothesis about slight difference between these two ´arousal´ variables.

5.1.2.6. Blood volume

The maximal blood volume constriction appeared as a response to aversive shock. The blood volume dilation was particularly large during Arithmetic task-execution. This parallels the result of Williams et al., (1975) and can thus be taken as a potential candidate for a variable specifically sensitive to these two demands separately. This contention can be supported also by the evidence about the differential sensitivity of the third-interval blood volume response to constrict during events experienced as unpleasant but dilate during cognitive effort when experiencing ´difficulty´ as manifested in the respective correlations with unpleasantness (r 0.13, p <.007) and difficulty (r -0.19, p <.000) ratings.

5.1.3. Multivariate patterning of arousal

The univariate examination permits a conclusion that two main patterns, viz. the pattern responding to motor demands and that accompanying cognitive performance, can be differentiated, in spite of some commonality between those two patterns. During Motor tasks skin conductance, pulse amplitude constriction and flexor EMG achieved the highest means. Also a large, but short-lived HR acceleration typically accompanied a fast motor response. Cognitive tasks produced a HR-acceleration of longer duration and the other main contributors in related contrasts were pupillary dilation, orbicularis oris EMG and also blood volume dilation.

Stimulus events a) elicited skin conductance responses, b) were accompanied by most stable respiratory cycles and c) did not affect heart rate or EMGs. Imposition of an emotional component like aversiveness to stimulation, thus producing a threat, affected most consistently skin conductance and blood volume constriction, but appeared also in flexor EMG as an increase of response probability. The latter effect may, however, be an ´artifact´ related to a reflexive muscle ´startle´ resulting from the shock.

In the multivariate evaluation of response patterning the thirteen measures sufficed to contrast the conditions very significantly. Most of the variables tended to compound to one of the main types of conditions, viz. to motor, cognitive or sensory/stimulus conditions. Almost all of the variables appeared to have sufficiently independent roles to enter with at least F >2.0 criterion into further calculation of SWDA. Although the correlative relations between single variables were low, there was such redundancy between variables that several from these might be specifically prone to respond to the same event type. The most relevant variables (viz. the same which were revealed in the univariate analyses) within each condition type tended, however, to contribute independently, ie. to respond to different aspects or via different subjects, in forming the contrast to other conditions.

In the present sample of conditions the main common source of variation seemed to result from demands related to somatic activity. Only flexor EMG was specific enough not to associate clearly with any other pattern. Most of the other measures made contributions to at least one of the two other patterns. This means that a component of variation presumably common to somatic activity, although regulated on the central level rather than resulting from peripheral activity (Obrist, 1976) is present in many contexts.

It seems apparent that different forms of somatic activity, eg. overt responses and more or less general isotonic tension including covert somatic activity, tend to be reflected in heart rate more generally than in some other measures. According to Pribram and McGuinness (1975) and McGuinness and Pribram (1980) during anaerobic metabolism an increase in isotonic tension is accompanied by heart rate acceleration and decrease of isotonic tension by deceleration of heart rate. They have collected evidence to argue that problem solving activity or reasoning is related to the increase in isotonic tension and categorization activity (ie. rejection and intake in the Lacey´s conceptual scheme, respectively) to the decrease in it. This offers an alternative explanation to HR changes by introducing somatic activity as a critical feature.

It seems that Pribram´s and his colleagues´ (1975, 1980) casual typology of activation phenomena - taking into account its simplicity - matches relatively well in several single aspects with the present results. It suggests a parallelism between ´arousal´ (phasic responsivity to input) and emotion. This is reflected especially in skin conductance which displays orienting activity with an associated habituation function and at the same time special sensitivity to reflect changes related to emotional avoidance (shock condition). This typology also combines ´activation´ and motivation (in a sense of getting ´set´ to respond) which refers to active participation in the task-related activities. This seemed to be accompanied especially by cardiac and somatic activity. The latter especially in the orbicularis muscles. They also distinguish ´effort´ as an attentional activity reflected in a compound of those two ´processes´. It was present here in several forms: 1) in mere somato-motor form as manifested during overt motor activity in flexor EMG and fast HR-acceleration and 2) as cognitive effort accompanied by longer HR increases and orbicularis activity during the task performance in Cognitive conditions. One form of effort may also be 3) the coping activity which is reflected in the anticipatory responses to avoidable events. This was especially present in skin conductance.

Pribram´s typology may be speculated to be applicable also to the description of the temporal course of physiological changes observed between the onset of S1 and the offset of the S2-related activity. Some evidence to permit a temporal differentiation of orienting (Pribram´s ´arousal´) and anticipatory behavior (set to respond) between S1 and S2 was observed. It appeared mainly in the former´s differential suggestibility to habituation and in the difference between these two in the specificity with respect to the S2-demands. This would allow a further specification of Pribram´s distinctions on a psychophysiological level. Analyses of the present results, however, revealed also that most of the immediate (first-interval) ´arousal´ responses to the S1 onset already show specificity and therefore it cannot be categorized unambiguously to the class of arousal but rather to that of ´activation´ in Pribram´s terminology.

In the analysis of the temporal course of physiological changes during a two-stimulus trial the S2-related physiological activity would represent mainly the ´effort´-component in Pribram´s typology. The same measures which reflect some form of ´arousal´ or ´activation´ in the above sense may have in different combinations - as described above - effort-related manifestations.

In all, however, the above typology, as well as the other available developments like that of Lacey and Fowles, do not suffice even for a description of the consistent features of the present findings. These show that further theorization is needed for understanding the variations, patterns and modifications of physiological changes manifested in these typically - although singly - studied conditions in psychophysiology.

5.1.4. Physiological arousal, activation and performance

The findings are consistent with the presently general view in psychophysiology that it is important to orient towards researching the qualitative differences in physiological arousal patterns instead of following the tradition of activation theory, which grossly oversimplifies reality. Even the most recent versions of activation theory - as formulated by Duffy - do not realize the role of other than energetic aspects of activity in explaining the situational specificity in the manifestations of cortical, autonomic and somatic arousal (eg. Duffy, 1972, 578). Nothing in the present results supports the contention that psychophysiological responses only reflect energetic and no directional aspects of activity. The directional aspect appears in the demand-specificity of the ANS-SNS responses, viz. in their task- or goal-related patterning.

Quite comprehensive data is offered in support of the critics of activation theory. The findings are compatible with the claims of eg. Näätänen (1973) and Hockey (1979) about the necessity of finding out the qualitative features of physiological arousal as these are related to the situational requirements.

The appropriateness of a physiological pattern with respect to the task in question may influence also behavioral efficiency. This central aspect of activation theory was not at the focus of the present problem setting, but some related observations could be made. The reaction time condition allowed a correlative analysis of RT-performance and physiological responses preceding and accompanying the performance. It was shown that the preparatory physiological patterns can explain a substantial amount of the performance variation. The best explanation was achieved in Fully Informed group whose preparatory adjustments probably match better with the optimal one. However, also the more varying, less specific anticipatory responses of Noninformed group revealed components which predicted significantly the RT-performance.

A further analysis of this preparation-performance covariation might be useful in specification of the physiological patterns related to specific task demands. In this case it seems, however, that the pattern which best predicts the reaction speed is different depending on the advance knowledge subject has about the task which is to be performed. In the case of noninformed subjects the best predictor of RT was the HR-acceleration during ISI. It singly achieved a significant explanatory role and other variables failed to add significantly to the correlation between reaction time and the physiological predictors. In Fully Informed group HR, FPA and frontal EMG and respiratory behavior explained together highly significantly the RT´s variance. These showed that when the pattern included as concomitant features the lack of HR and frontal EMG decrease, constrictive FPA and regular respiration the total preparedness for fast motor responses was markedly reduced. The multiple correlation of the HR, pulse amplitude, frontal EMG and respiratory behavior to reaction time was 0.88, which means that these variables explained as much as 77 percent of the RT´s variance. The differential preparation of NI- and FI-groups might be interpreted to reflect a variation which differentiates a ´generally valid´ adjustment for attentive behavior as represented in the pattern of NI-group from a specific pattern for fast motor response in FI-group.

Few features in the present results are anyway consistent with the arousal-energy consumption hypothesis. However, the rough correlation between the ´difficulty´ ratings and most third-interval scores may be taken as support for a contention that some common component may be separable from the total variance. Although the correlations are highly significant, the explanation value of even the highest of these (HR r .32, p <.000) is low (less than 10 %). Thus other sources of arousal are more important than that which might be interpreted to be compatible with activation theory.

The interaction between, on the one hand quality of a particular arousal state rather than mere arousal level, and on the other hand the quality of the task demand rather than eg. complexity or intensity of the effort can be considered a question of special importance for a psychophysiological study of arousal. This seems to be a conclusion of related studies independent of the approach they have used. Hamilton, Hockey and Rejman (1977) have arrived at it on the basis of findings about arousal-performance relationships, the present author on the basis of differences in arousal patterns resulting from the varied demands to which subjects were exposed.

5.2. Anticipation

Anticipation has not been in the center of psychophysiological study. Therefore - after the above ´introduction´ with related experimental data - a brief review of the background of the use of the anticipation concept in psychology and psychophysiology is in place to offer some further basis also for evaluation of the findings. The directly related earlier findings are then compared with the present ones.

5.2.1. Anticipation: conceptual background

The concepts of anticipation, preparation, set and expectancy have been frequently used in psychology. These refer to forms of pre-event activity or ´preactivity´ which mostly are studied as covert and implicit rather than directly observable phenomena. It has been usual to provide related constructs with important roles in the regulation of behavior. William James (1890) spoke about anticipatory preparation, Woodworth about preparatory reactions/set (1918, 1921, 1938) or goal set (1937), Bartlett about schema or anticipation (1932), Tolman about expectancy (eg. 1932), Mowrer about preparatory set (eg. 1938) and Hull about fractional anticipatory goal response (eg. 1943) to mention only a few of the most well-known users and uses as central anchor concepts of wide theoretical constructs.

Before Second World war ´set´ was considered to have a generality similar to a psychological concept such as stimulus and response (Dashiell, 1940). It had a superfluous multitude of varied usages as shown by Gibson (1941).

Later the use of the set concept has been less frequent and mostly more specific (with a few exceptions like that of Uznadze (1966)). However, the interest in preactivity phenomena has not faded. Related influential concepts have included terms like expectation or perceptual readiness which Bruner and Postman (1947) utilized in explaining perceptual behavior, stimulus and response set which Broadbent (1969) thought of as important components of attentive behavior in sensomotor performance, and the perceptual set (1967) or anticipatory schemata (1976) concepts of Neisser to mention only the most salient usages. A comprehensive list of the contexts in which preactivity concepts have been used in psychology is given by Lyytinen (1982c).

Generally speaking it seems that some expression related to preactivity is a ´must´ in a theoretical construct introduced for explaining human behavior. Therefore its more explicit analysis and ´operationalization´ for concrete empirical study seems necessary. The present argument is that a psychophysiological analysis of preactivity may make some contribution also to a more general understanding of preactivity phenomena. Monitoring the psychophysiologial, subsensorial level of anticipation offers an access into preactivity at the time it occurs instead of restricting the empirical approach to mere inferences based on the post-event behavior. It also permits observation which does not intrude into and thus confound the studied phenomenon.

5.2.1.1. Psychophysiological preactivity

Anticipation, set and preparation concepts have been used by many researchers of early psychophysiology (Tarchanoff, 1890, see 1976); Darrow & Solomon, 1934; Darrow, 1937; Freeman, 1939; Davis, 1946) as labels of various aspects of physiological reactivity measured in the pre-event periods of warned stimuli. Anticipation has also been introduced as a concept of central theoretical importance to psychophysiology in the later era (Germana, 1969) and once again quite recently (Lang, 1979). The idea of preactivity (in terms of eg. preparation, expectancy and anticipation) has also been centrally present in the general theories of some brain scientists both in the past (Sherrington, 1952; Sperry, 1952; Anokhin, 1974) and recently (eg. Granit, 1977; Grossberg, 1980).

Psychophysiologically not much has, however, been achieved on the pure empirical level thus far. Two psychophysiological research traditions have so far explicitly touched on preactivity in empirical terms. One is the wide research of conditioning which examines conditioned reactions often as anticipatory physiological responses. The other is the study of the electrical slow wave activity of the brain originated by Walter and his associates (Walter, Cooper, Aldridge, & Winter, 1964) with their discovery of the contingent negative variation or expectancy wave. It represents a multicausal increase of negativity in the brain´s DC-potentials in advance of various intended activities. An associated pre-event wave more closely related to motor preparation (Bereitschaftpotential) was identified quite soon thereafter by Kornhuber and Deecke (1965). The state-of-the-art in slow wave activity research, as it is related to the psychophysiology of anticipation is reviewed by Lyytinen (1982a). Lyytinen (1981) also made some experimental attempts to specify the interrelationships between autonomic and cortical pre-event changes. The cortical manifestations are not discussed here in more detail because the present concern is confined to the autonomic-somatic phenomena.

5.2.1.2. Anticipation versus conditioning

The choice of using the concept of anticipation, instead of eg. conditioned reaction in the analysis of autonomic pre-event phenomena, hints at the author´s preferences for the most adequate level of explanation in human psychophysiology. These preferences have emerged along with experience with the psychophysiological study of conditioning in humans (Lyytinen, 1970, 1974, 1975a,b), and reviews of related research (Lyytinen, 1975c, 1982a, 1984).

In sum, the problem is in the emphasis given on the cognitive processes in human conditioning. Theoretically speaking the problem concerns the inevitable interaction between the so called second and first signal systems, a widely neglected aspect in conditioning studies. Empirical evidence from human conditioning studies offers good basis for a hypothesis that behavior as it appears on the autonomic-somatic level reflects multiple interactions between these two system levels in which the second signal level mainly dominates. Strong single experimental cases to support this contention come eg. from studies of Wilson (1968) and Grings et al., (1973) and Lyytinen (1970, 1974), which demonstrate the sensitivity of autonomic ´CRs´ on verbal factors in a cue-reversal condition.

The modifications of autonomic responses are not so rigid as conditioning explanations lead one to expect. Cognitive processes are strongly involved in autonomic activity. Recently this has became more generally accepted also among psychophysiologists working with conditioning problems. That it is possible to find alternative theoretical explanations to conditioning is nicely demonstrated by Öhman (1979) in his information processing view about the ways autonomic response modification may proceed in conditioning settings.

The experimental plan of the present study started from the contention that cognitive rather than conditioning factors dominate human autonomic behavior. The most general reason for including the monitoring of pre-event responses in the study was to contribute to further understanding of the forms and contents of autonomic preactivity.

An overview of the results supports this general contention. The findings eg. show how mere knowledge about important future events produced manifestations on the autonomic level. Repetition of stimulus pairing, the main basis of conditioning, attenuated rather than accentuated the changes which might be formally identified as conditioned responses. With a very short explicit prior learning, verbal information about a future event was sufficient for producing autonomic ´preparations´ which verifiably were related more immediately to the events in the near future (S2) than to preceding stimuli thus representing rather pre- than post-event activity.

Notwithstanding the wide interest in the preactivity phenomena, such as ´set´, in the past and their obvious relation to the above problems of conditioning (Gibson, 1941) as they are experienced today, no alternative, related theorization about preactivity exists in the present literature. Therefore the present level of discussions is compelled to concentrate mainly upon mere empirical findings based on discrete but related single hypotheses. These come from psychophysiology of arousal /activation and of preception.

5.2.1.3. Autonomic-somatic preactivity

In general the earlier theories and empirical data about anticipation have shed some light on its varied levels (Lomov & Surkov, 1980), but not much is known specifically about its autonomic-somatic forms. This is surprising because ANS can be expected to offer particularly appropriate information about the basics of anticipation. As described in the introduction, it represents the nervous system level which has the function of integrating and realizing the internal preparations of the human performer when he or she is being faced with any challenge in the immediate future. It is a central participant in all activity to optimize an organism´s survival chances (automatic preparation level) or effectiveness with respect to goal-directed behavior (level of controlled processes).

It is worth mentioning that although explicit empirical evidence is surprisingly scarce, the preactivity in autonomic and somatic nervous system has been accepted as a fact-like phenomenon even in dictionaries. Thus eg. Webster explicitly tells (also cited by Schwartz et al., 1981) that significant environmental challenges are anticipated before any overt (performed or not performed) acts by physiological departure from homeostasis as manifested in neuromuscular, respiratory, cardiovascular, hormonal, and other bodily changes.

5.2.1.4. Arousal and anticipation: methodological remarks

A literature search of multivariate evidence about pre-event response patterns does not offer much psychophysiologically relevant material. Nor is there much earlier research to verify the existence of event-related autonomic-somatic anticipation. This presupposes demonstration of event-specificity in the response patterns with explicit documentation of their relation to the events for which an organism is preparing. Thus to be relevant for this purpose the research should include both (1) a comprehensive arsenal of concomitant measures to outline the patterning as well as (2) several conditions or events for comparison to evidence the demand-specificity.

Interest in taking the first condition seriously has been lowered by the opposite view of activation theory about arousal responses as a homogenous, unidimensional mass of changes. One explanation for the lack of related studies concerning anticipatory behavior specifically may follow from a similar reductive account of Cannonian thinking in which autonomic preactivity is confined to preparation for ′flight or fight′, ie. similar to a mere one dimension of activity accountable for thoroughly in quantitative terms. This reduction has concerned both the expected manifestations (one ANS measure represents all) and the demands on which the responsivity is thought to be based (viz.there is only one effective ′dimension′, energy mobilization).

A careful confirmation of the specificity of response patterns, with respect to demands on which they are supposed to be based, permits also the exclusion of extraneous activational effects which easily intrude into any paradigm used in the study of anticipation. Such are the effects resulting from uncertainties about the expected events. Thus far S1-S2 paradigms similar to the one used here but with one S2-type presented with varying probabilities after S1 have been used as contexts for quantifying uncertainty effects (eg. Higgins, 1971; Jennings et al., 1971; Öhman, 1971).

5.2.2. Psychophysiology of anticipation: comparison with the earlier findings

The earlier studies which are most relevant for the present purpose have (a) monitored 2-3 concomitant measures at best (most typically heart rate, skin conductance and/or one further variable like pulse amplitude or muscle activity). Very few have (b) compared qualitatively different conditions for demonstrating specific forms of preactivity. If (a) has been fulfilled then (b) has mostly been not. Some studies have, however, been published in which minimal criteria for finding appropriate data for the present purpose have been fulfilled. This means that at least two conditions have been compared with any autonomic and/or somatic pre-event measure(s). Most of the condition comparisons have included manipulation of some quantitative feature of the stimulation (eg. shock probability) or task (eg. the expected task difficulty). Very few have tested hypotheses about qualitative differences in pre-event responses as functions of event type.

5.2.2.1. Anticipation of an aversive event

The best known form of pre-event autonomic response is the increase of electrodermal conductance in anticipation of an informed aversive event (eg. Öhman, 1971; Lyytinen, 1971). That this variable is particularly responsive to anticipation of an electric shock was demonstrated also in the present study. A consistently higher skin conductance response preceded the shock than preceded most other S2-events in Fully Informed group.

The anticipatory responses of heart rate were lower to aversive events than to any other condition. This is understandable given the insensitivity of heart rate in responding to aversive stimuli (as discussed above) and assuming that these two response types resemble each other. However, when shock or loud tone is delivered after a fixed period from a warning stimulus the ISI being known by the subject, the ´attentional´ rather than UCS-copy-like responses tend to dominate the pre-event heart rate pattern. This appears to be the case at least with the mildly aversive intensities used in most related experiments. The typical pre-event HR-pattern is either a mere deceleration or a biphasic acceleration-deceleration response. The accelerative peak exceeds the prestimulus level but the decelerative phase just preceding the critical event returns it to the base level or below it, depending on the duration of the anticipatory period (Dronsejko, 1972). Often this means a near zero mean response in relation to the prestimulus level (eg. Gaines et al., 1977) or the dominance of an accelerative component which decreases as a function of trial repetition (Bankart & Elliot, 1974).

The present HR-results parallel the typical acceleration-deceleration waveform found in these earlier studies. The same general pattern was present in all groups who knew about the temporal schedule. This common form is also visible in the curves of all six conditions, which show that it is merely ´attention´-specific. Aversive stimulation such as the present sS did not markedly modify this basic waveform.

Condition comparisons reveal that the total accelerative change preceding aversive stimuli is smaller than the one that precedes events requiring cognitive or motor activity. This might be accounted for by the interpretation that in the case of unavoidable noxious S2 no activity is functional from the subject´s point of view while the latter conditions demand his active involvement. It seems to be the active coping that is consistently accompanied by larger heart rate changes. In this anticipatory activity HR differs from skin conductance. The latter seems to be more sensitive to differential anticipatory responding also when no mental effort or motor activity is needed.

The HR results parallel the only available earlier comparisons between conditions, viz. the comparison of anticipatory responses to shock with responses preceding the imperative stimulus of RT-task (Lyytinen, 1981; Somsen et al., 1983). A prewarned RT condition is accompanied typically by a consistent biphasic increase-decrease waveform, which was shown in both of these and present studies to be more pronounced and less decelerative than the changes which precede prewarned aversive shock.

It can be concluded that the two variables, skin conductance and heart rate, display relative directional fractionation in anticipation of an unpleasant, unavoidable event. In this condition compared to the others skin conductance shows a pattern of highest relative anticipatory increase while heart rate responds with the lowest mean pattern.

A further aspect in the response pattern is worth noting. Frontal and orbicularis EMG responded with more decrease during anticipation of shock than for other conditions in the informed groups. Because tone-Stimulus also was preceded with a similar pattern these anticipatory responses may be interpreted to be specific to anticipation of sensory stimulation rather than to mere aversive events.

5.2.2.2. Attentional modes and coping

Heart rate would be expected to reflect environmental rejection in the case of aversive stimulus like shock with acceleration. The present data did, however, reveal this HR-change to be neither a response to shock nor in anticipation of it. It may be ´adaptive´ to anticipate an unpleasant event with a pattern which Lacey assumes to optimize the ´intake´ of environment if effective environmental search may offer means to avoid or reduce the impact of the coming noxious event. On the other hand a similar mode of attention might be adaptive also when preparing for any response presupposing sensory intake as a start-signal. Thus the more decelerative HR responses in other than Cognitive conditions where preparation for ´environmental rejection´ dominates might be interpreted as representing some kind of active coping.

Related coping activity may have different forms. HR acceleration has been shown to accompany anticipation of very unpleasant stimuli (like spiders or crushed human bodies) especially when presented to phobic and anxious subjects (Klorman et al., 1975; Shiomi, 1974). Under these conditions HR also displayed repeatedly accelerative anticipatory responses.

The physiological responses accompanying preparation for unpleasant events have been reported to be dependent also on the individual strategy the subject takes to face the conditions (eg. Gal & Lazarus, 1975). Most explicitly the variations of avoidance strategies are demonstrable between animal species, of which some respond with immobility and some others with approach to the same dangerous object (Obrist et al., 1974). Physiological effects of varied strategies have been demonstrated also in human subjects (eg. Geer et al., 1970; Hokanson et al., 1971). What pattern actually occurs seems, however, to be dependent on several condition- and individual specific variables (Averill, 1973).

In the present study the variation in types of coping between the different conditions influenced the physiological dependent variables much more than the individually varying ´strategies´ as shown by the multiple statistically significant contrasts between conditions. At the same time the significant differences between the three differently informed groups probably are partially a result of distinct ways to approach the critical events. The comparisons were, however, planned for rougher contrasts and thus do not permit any direct and unambiguous conclusions related to possible effects interpretable in terms of coping strategies.

One indirect way to search for physiological correlates of subjective ways to cope with events is to examine the correlation between anticipatory response patterns and subjective ratings about ´feelings´ related to the expected events. The present data permits correlating pre-S2 physiological scores with unpleasantness and difficulty ratings in the Fully Informed group.

The findings reveal how event-specific these correlations supposedly related to physiological anticipatory coping responses may be. There was eg. a significant positive correlation between the unpleasantness rating of the shock and related anticipatory frontal and orbicularis EMG decrease (0.40 and 0.63) but in the other condition relevant for unpleasantness rating, viz. loud tone, an opposite correlation was revealed. Both of these EMGs displayed significant positive correlations with increase (0.41 and 0.46, respectively) of activity. Difficulty-rating correlated positively with first- and second-interval heart rate mean increases (from the pretrial level) and with pre-S2 blood volume dilation across conditions but these failed to show significant correlations in the within-condition analyses. These findings demonstrate that some physiological measures may covary quite highly with such experiential qualities related to coping as the difficulty of the task, but their further study is needed before any related conclusions can be drawn.

5.2.2.3. Anticipation of a cognitive task

Cacioppo and Petty (1979b) compared anticipatory patterns preceding different types of argumentation. Monitoring consisted of heart rate, respiration and several EMG channels. When anticipating counterattitudinal advocacy, a pattern of increased oral EMG, cardiac and respiratory activity was found. No concomitant EMG increase could be disclosed in the other locations. This is almost exactly the pattern found in the present study during pre-S2 intervals of the cognitive tasks. In the results of Cacioppo and Petty this pattern was not found preceding expected proattitudinal or neutral communication, as it was not seen in the other conditions but cognitive ones in the present study. In addition to similarity of physiological patterns also the task demands apparently resembled each others in these two studies. Counterattitudinal advocacy leads one to spend cognitive effort on defending one´s own viewpoint similarly as arithmetic and memory task-performance presuppose effort for internal processing.

The other studies in which the anticipatory response to cognitive task execution has been monitored have included not more than one or two physiological channels such as, exclusively cardiac (Montgomery 1977; Scher & Furedy, 1982; Schwartz & Higgins, 1977) or cardiac and electrodermal (Lyytinen, 1978; Tursky et al., 1970) effectors. For the present case relevant condition comparison was made only in Schwartz and Higgins' study in which mental and motor anticipations were contrasted. All of the above have reported consistently some accelerative heart rate response in anticipation of prewarned cognitive task independent of the exact type of the task, warning stimulus or its duration. But, and again in line with the present results, similar acceleration was also found preceding motor task in the Schwartz & Higgins (1977) study. In the present study the HR acceleration was larger in anticipation of the cognitive tasks than of Motor task, which was preceded by higher pre-event acceleration than the last three conditions.

Anticipatory skin conductance or skin potential responses have been shown earlier to reliably anticipate a prewarned Arithmetic task (Tursky et al., 1970; Lyytinen, 1978) and this was replicated in the present study. Only Motor task and sS were preceded by comparable anticipatory SC-responses than Arithmetic task. These anticipatory responses deviate from the general pattern characterizing the responses during task executions. Skin conductance was relatively less responsive during cognitive performance. This also is a compatible finding with the earlier results; both in Lyytinen (1978) and Tursky et al., (1970) the means of the anticipatory responses were even larger than those of the executive phase although in other conditions the firsts are markedly lower. In the present data the difference was only relative; the absolute response amplitudes accompanying cognitive executions were clearly higher.

5.2.2.4. Anticipation of a sensory task

Anticipatory HR- and EMG-responses to sensory discrimination or detection tasks have been studied extensively by Coles (1974) and Duncan-Johnson (1974, 1975, 1979). In most of their studies a warning stimulus has preceded a condition in which the task has consisted of a detection or discrimination of an auditory stimulus. In these studies the warning has been found to be followed by a 2-4 beat acceleration succeeded by a similar or larger deceleration. When the difficulty of the task was varied by informing about it in a warning slide (Coles, 1974; Duncan-Johnson & Coles, 1974; Coles & Duncan-Johnson, 1977) it resulted in a larger anticipatory deceleration for the more difficult trials, a finding replicated by Gaillard and Perdok (1979). The requirements to respond motorically, as in the present RT-condition or in the latter phase of the stimulus sequence of the Coles and Duncan-Johnson's (1975) study, produce an accentuation of the accelerative-decelerative-alteration of heart rate. Although it was significant in the present RT-data only in Partially Informed group, the mean difference in the deceleration between conditions which included motor requirement or not, was even larger than what was found in the above-mentioned studies.

Eg. Schell & Catania (1975) have made direct attempts to show that threshold auditory stimuli are detected most effectively when the event has been preceded by the deepest heart rate deceleration. The observed correlations between anticipatory HR-changes and RT-performance in the present study can be taken as evidence compatible with these findings and the Lacey hypothesis on which related research has been based.

Coles and Duncan-Johnson did not find covariation between heart rate and orbicularis oris EMG during anticipation of the sensory stimulation/task. In the present data orbicularis EMG increased equally during preparation for Arithmetic and Memory tasks and contrasted all these three tasks from the Stimulus conditions. Heart rate did not reveal a reliable difference between Sensory task and Stimuli. Otherwise the response profiles were quite similar. Thus heart rate and orbicularis oris EMG disclosed a covariant increase during preparation for verbal processing or motor activity but EMG was more sensitive to increase also during anticipation of sensory performance.

HR-result is compatible with earlier results of Cacioppo & Petty (1979a, 1981) and with Pribram's interpretation of the Lacey's hypothesis discussed above. Both HR and orbicularis oris EMG can be identified as prone to respond to demands including active effort. The orbicularis measure may, however, be even more sensitively affected than HR in reflecting also sensory processing, while HR tends to contrast conditions according to the 'intake'/'rejection' of the environment-dichotomy also during preparation for the activity.

5.2.2.5. The verbalization requirement

In addition to the Laceyan distinction based on attentional behavior, the cardiac-somatic covariation hypothesis based on the work of Obrist and his group and Pribram´s integration of these two, also one further theoretical view exists to explain patterning of psychophysiological phenomena. It is the hypothesis of Campos and Johnson, on which no stand has yet been taken, although it is quite interestingly related to our data.

In all conditions, requiring active performance, except RT-task, Ss had to verbalize an answer. Campos and Johnson presume this verbalization requirement to be a critical factor regarding the resulting psychophysiological response pattern. They have published evidence that with such a requirement no fractionation between heart rate and skin conductance can be proved in sensory (Campos & Johnson, 1966) or affective (Campos & Johnson, 1967) conditions. Especially the first study is of interest here. Campos and Johnson showed that a task presupposing visual attention is anticipated with a decrease of heart rate and increase of skin conductance only when no verbalization requirement is present.

In the present experimental setting three relevant conditions with a verbalization requirement could be compared. According to Lacey HR should decrease in a Sensory task condition and in the two more purely cognitive conditions both HR and SCR should respond with increase. Following Campos we would predict HR to accelerate also in the sensory task because of the verbalization requirement.

In relation to the anticipatory response the verbalization in our procedure was required to be given quite late - four seconds after the offset of S2 slide. Thus one would expect less fractionation during the later, executive phase than during anticipation. In one respect the results reveal both of the theories to be oversimplified. Skin conductance response differentiated the two compared conditions both during anticipation and execution. It responds more to cognitive processing demands than to the sensory processing demands. Heart rate was higher during cognitive than during sensory tasks during both anticipation and execution, independent of the equal verbalization requirement in both conditions. The finding is in this compatible with the Lacey´s hypothesis. However, the executive response of Sensory task was also accelerative. This last finding tends to show that the verbalization requirement, although delayed, may have had some accelerative effect on the heart rate, but during anticipation the acceleration was relatively even more pronounced instead of being less pronounced or merely decelerative, to follow the predictions of Lacey´s theory. Thus the present findings lend support to a contention that both of these hypotheses are too narrow to explain the empirical results in a representative way.

5.2.2.6. Comparison of pre- and post-event response patterns

5.2.2.6.1. General remarks

When an expected event sufficiently involves the subject the physiological manifestations accompanying its anticipation and impact have been shown to resemble each other both in hormonal and autonomic level. This seems to be the case at least when anticipating and experiencing hypoxia as shown by Mefferd and Wieland (1966). There is some earlier evidence also of comparability of response patterns accompanying preparation and execution of movements (Mitchell et al., 1958). This general similarity was characteristic of the responses observed in the present experiment, too, as detailed above.

5.2.2.6.2 ´Typologies´ of arousal

The psychological distinctions between activation types offer a possible starting point for a search of types of the physiological patterning of anticipatory arousal. Both may be understood as manifestations related to mental representations of the state of events, and neither necessarily has any immediate external ´elicitator´.

Thayer (1970, 1978) has specified both theoretically and empirically a psychological categorization of activation. One of the resulting main distinctions replicates a typology which has its origin in Cattel & Scheier´s (1961) psychometric differentiation. It contrasts two forms of activations, viz. distress or anxiety, and effort. The discussion above about executive (third-interval) arousal revealed how these two main types of arousal patterns may be differentiable also psychophysiologically. A further distinction dividing effort into two forms: viz. cognitive and motor, was shown to be necessary for explaining the main variation in the third interval physiological responses. It is of interest here to test how far also anticipatory physiological responses show the same differences between stress- and effort-related conditions and if the latter additionally fractionates into motor and cognitive pre-event patterns.

Some support of this typology was found. The univariate analyses revealed that heart rate responded specifically in advance of cognitive tasks by showing consistently more acceleration than in the other conditions. Orbicularis EMG responded more in advance of both sensory and cognitive tasks and increased with greater probability during preparation for Motor task. Similarly pulse amplitude, flexor and frontal EMG tended to respond specifically to motor (RT) task. Only skin conductance was sensitive to show reliable responsivity in advance of informed shock exposure. It was, however, as responsive preceding the motor and almost as responsive in anticipation of Arithmetic task.

Thus the present physiological evidence permits a differentiation of two ′effort′-related patterns also on the basis of the pre-event data. The pre-event patterns of Motor and Cognitive conditions were quite well separable not only from responses preceding the sensory situations but also from each other. No measure, however, disclosed any exclusive threat- or distress-related sensitivity to shock. In this respect the present results failed to support the similarity between typologies constructed on the basis of psychological and physiological data. It must be added that this failure may follow also from insufficient representation of threat/distress variable in the present experimental procedure. The used shocks were possibly too ′mild′ stimuli to produce threat in the present Ss who were accustomed to these in their daily work with electrical instruments (as was revealed in the post-experimental interviews).

These pre-event response-specificities were not exactly the same as those which characterized the stimulus- or task-produced activity, but many similarities can be discerned as will be detailed below. The main difference between the above ′typologies′, based on psychological analysis, and the types of physiological patterns found here, was a less clear differentiation of a specific ′distress′ physiological pattern. Instead the two Stimulus events and Sensory task were often preceded by quite similar responses. Some physiological variables, like skin conductance and vasomotor constrictions of BV and FPA showed, however, some tendency to manifest contrasts between shock and the other conditions including sensory demands, viz. tS and Se, which might allow a speculation about a fourth main type of arousal pattern.

5.2.2.6.3. Variable-specific comparisons

Heart rate was one of the measures shown to accelerate reliably during the cognitive task execution. The first accelerative component of HR following immediately the S1-slide was similarly accentuated in the FI- and PI-groups during those conditions. The same resemblance was visible in the FI-group also during Motor condition, although the similarity was not quite as clear. In Stimulus conditions HR changes were smaller both during anticipation and experience as these were in the sensory discrimination task. Responses preceding these three sensory events and cognitive ones could be reliably differentiated. Motor task was anticipated by an acceleration falling between these two patterns. Thus the pre- and post-S2 accelerations followed a similar relative order of magnitude across conditions.

There are some earlier studies in which heart rate has been recorded during a forewarned Motor task requiring mostly a RT response (Chase et al., 1968; Pugh et al., 1966; Schwartz & Higgins, 1971; Stamps et al., 1981). These have revealed the same HR- pattern as found in the present study, viz. triphasic response with a marked acceleration in the middle of the anticipatory period independent of the variations in its length. Schwartz and Higgins (1971) demonstrated that a mental intention or ′active′ imaginary execution of the motor response required in the RT-task already suffices to produce a similar waveform when the activity is exactly timed. Thus overt motor response may not be necessary for producing this general waveform. That the same pattern - though in a less pronounced form - was found also in the anticipation of other task conditions including the sensory discrimination task in our data, is compatible with this kind of thinking.

Johnson and May (1969) and Cohen et al., (1980) have reported almost identical waveforms in a standard prewarned RT-task and in a time estimation task when both tasks have the same temporal parameters but the latter includes no requirement for sensory detection of an imperative stimulus. Thus it seems to be the mere mental act of preparation for covert or overt response and the processing of the appropriate information (temporal schedule of attentive behavior) which determines the general time-related topography of the waveform. The further demands included in the specific task have additional effects superimposed upon this general pattern, as shown elsewhere in this paper. The resemblance of pre-event changes with the typical post-event response in any condition requiring active performance seems to concern first of all the middle part of the pre-event waveform, viz.

the acceleration, which also was shown here to be most clearly affected by these additional effects.

Skin conductance responded in anticipation of shock and Motor task, which it did not significantly differentiate. It also failed to contrast these clearly with the anticipatory responses of Arithmetic task. The anticipatory second-interval amplitudes followed, however, about the same order as the S2-responses. An exception resulted from the reduced third interval response to shock in Fully Informed group, which can be interpreted as resulting from the preception effect as discussed later.

The threat sensitivity of skin conductance has been widely present in the earlier literature in which skin conductance is mostly used as a measure of shock-elicited anticipatory arousal (viz. in the conditioning study). Much less direct evidence is available about its sensitivity to motor demands. Theoretically it is an acknowledged fact (see eg. Edelberg, 1972, 1973), but direct empirical evidence about anticipatory activity is scarce. The most relevant evidence comes from Pugh et al., (1966) who have showed it to be especially prone to reflect a ˊmotor setˊ, as mentioned above.

Pulse amplitude responded with the largest constrictions during anticipation of Motor task as it did during motor execution. The shock was not preceded by differential constriction in the present study nor did the pulse amplitude respond to the shock itself. This is opposed to the general view about the sensitivity of pulse amplitude to constrict as a response to stressful events as revealed by its common role in aversive conditioning literature. (It must be added, however, that related experimental evidence is also much scarcer and less consistent than that based on skin conductance measures).

Cook (1974) did not find any data about vasomotor responsivity in RT-conditions in her review. However, later (1976) Bower and Tate have demonstrated clear anticipatory vasoconstriction to an imperative RT-signal. This parallels the present result. Both anticipatory and executive (third-interval) response components of pulse amplitude displayed constriction in the RT-condition. The same resemblance between pre-task and task-related responses was evident also in cognitive tasks conditions, but only motor demands produced a constriction which could be reliably contrasted with the other conditions. On the basis of present findings pulse amplitude seems to be reflective of effort-related activity both before and during a performance situation more reliably than eg. some distress-related arousal.

General tension, as reflected in **EMG** especially outside the head area, eg. in flexor (Goldstein, 1972), has been reported to increase already during preparation for motor or RT-response (Davis 1946). This was discovered also in the present study. In the flexor and orbicularis but not as consistently in frontal muscles the relative probabilities of EMG responses resembled each other during pre- and post-S2 intervals. Orbicularis EMG was sensitive to change during both types of effort (motor and cognitive) and both pre- and post-S2 responses differentiated these conditions from the Stimulus ones. The other EMGs were not able to contrast any but the motor from the other conditions with either of their response scores.

Respiratory cycle duration, which showed clear contrast between motor and other conditions during the third interval tended to disclose a similar contrast already in anticipation of it. The **respiratory disturbances**-variable followed also this general pattern but the revealed parallelism between pre- and post-S2 score-profiles was, however, less pronounced. **Blood volume** changes also were less consistent than the other measures in this pre-post resemblance. Both of these variables were at the same time least reliable in displaying S2-related contrasts, which makes the lack of pre-post similarity more understandable.

Overall it seems that the preparatory autonomic and somatic response patterns were quite consistently similar with the post-S2 ones, although were typically less pronounced. Respiratory disturbances and blood volume displayed the only exception to the general regularity.

5.2.2.7. Anticipation and imagination

Anticipation can be seen as mental preparation for future. This may include use of mental imagination in varied forms, like mental rehearsal applied in sport training. Some related psychophysiological results exist and are relevant to the present discussion. One of these is that images may be effective ´stimuli´ in producing physiological reactions. Images about activity have been demonstrated to produce quite consistently heart rate increase from the baselevel of an alert state. The most consistent consequence of images about passivity has been the decrease of respiratory rate, while the heart rate decrease is more difficult to produce via manipulation of imaged states (Jones & Johnson, 1980; Buzard, Cowings, & Miller, 1975). There is also evidence of skin conductance responses to imagined shock (Yaremko & Butter, 1975; Yaremko & Werner, 1974).

The proven sensitivity of heart rate acceleration to accompany imagined activity-states or of skin conductance to respond to imagined aversive stimulation parallels the present finding about the pre-event responses in these variables. Their ability to contrast respective conditions (viz. those requiring effort and shock condition) during pre-S2 intervals was relatively the highest within the nine effectors which were monitored in the present experiment.

A second point of interest has been the comparison of the responses produced in a real life situation versus in imagined contexts. It has been demonstrated that the cardiac change related to tensing of muscles is similar but not identical to a response produced by its imagined counterpart (Jones & Johnson, 1980). In the present data the pre- and post-S2 HR equivalence was also relatively high.

Cardiac, respiratory and somatic activity has been shown to be more easily affected by images or imagined states than is electrodermal activity (Jones & Johnson, 1978; Lang et al., 1980; Carroll et al., 1982). The first mentioned physiological variables have even been demonstrated to respond more intensely to imagined scenes than to equivalent picture-produced sensory scenes (Carroll et al., 1982). In Stimulus conditions HR revealed this pattern also in the present study; the anticipatory accelerations were larger than the post-stimulus ones in both shock and tone conditions. This cannot, however, be unequivocally compared with responses elicited by an imagined versus a concrete stimulus, respectively, because also other factors very probably contributed to physiological responses preceding the stimuli, as discussed elsewhere in this paper.

Also in our data the anticipatory SCR amplitudes were clearly smaller than the third-interval responses but even these small SCR amplitudes successfully discriminated conditions into two main groups. Thus SCR may, however, quite effectively reflect differences between covert states at least if these are produced by leading Ss to anticipate related real events.

Lang (1979) assumes that the response propositions included in the scripts used to evoke images are the critical aspects in autonomic response evocation. This means that autonomic responses can be seen as preparatory responses or sets for activity. On the other hand Neisser (1976) theorizes that perception is based on anticipatory sets or schemata about the scenes so that these anticipations represent images (1978) and Sperry (1952) identifies perception with preparation to respond. Thus the relationship between anticipation, images and preparation to respond can be theoretically seen as very intimate.

The research is beginning to complicate the picture based on the empiric account of Lang, which presupposes that explicit response propositions should be present to work as ´stimuli´ for producing autonomic responses. Thus far self-produced images have been shown to produce characteristic autonomic-somatic responses more probably than images with mere stimulus propositions or mere visual stimuli. This has been explicitly demonstrated only with image scenes which are arousing rather than relaxing (Carroll et al., 1980). Lang et al., (1980) and Carroll et al., (1980) have shown that arousing image scripts allow image production with consistent cardiac and respiratory changes. Carroll´s subjects achieved these results even without any preparatory training.

Only the S1-events of our RT-condition included as explicit response propositions that have been used in the image script. Also the mere S1-labels of cognitive tasks (like ´memory´), however, sufficed to produce clearly specific responses, which might be interpreted similarly as image-produced responses. Also other of our findings refer to a possibility that event-specific anticipatory responses can be produced at least in some effectors without any reference to response propositions. The reliable anticipatory responses to shock offer an example.

Although this kind of evidence might be interpreted to show that event-specific ANS-responses can be demonstrated without presenting any explicit response propositions, no evidence exists for arguing that response-related material would not be covertly generated to participate in the creation of event-specific responses or related preparations or sets.

Use of image scenes for production of image-based states has offered a context to verify ´situational´ specificity in the autonomic-somatic response patterns. Schwartz et al., (1981) have succeeded in demonstrating a detailed ANS response specificity between different patterns accompanying imagined emotions of fear, anger, sadness and happiness. Measures consisted of systolic and diastolic blood pressure and heart rate. Most of these emotional states were significantly contrasted with at least one other state with at least one of the utilized measures. The multivariate tests failed, however, to contrast fear significantly from any of the other imagined emotional states.

There is some basis to compare this and the present study because in both studies psychophysiologically interesting states were contrasted with the purpose of testing whether the implicitly (ie. not directly stimulus elicited) or covertly (ie. including no overt manifestations) present states are separable by means of autonomic response patterns. The total success in classification by discriminant analysis of these emotional states was not quite as good as that of our data in separating the anticipatory states that prevailed during the six experimental conditions. The correct identification percentages were 40-50 % vs. 80 % , respectively, in these two studies.

The question about the comparability of imagined states and the anticipation ´state´ has been interestingly approached in the above cited Jones and Johnson´s experiments. In these the time-locked packing of images was always preceded by a ´think´ phase. It consisted of a time given for ´working through´ the material and thus permitting some kind of anticipation of the situation. Already during anticipatory periods the responses typically deviated from the baseline and followed almost a linear increase up to the image-phase responses. This effect has been demonstrated also in the facial EMG when thinking of emotional scenes, before and while imagining these (Schwartz et al., 1975). These results agree with the present ones.

5.2.2.8. Anticipation and interest

There is yet one specific context in which anticipatory responses have been studied. Lang, Öhman and Simons (1978) and Simons, Öhman and Lang (1979) have compared anticipatory slow wave and autonomic (skin conductance and heart rate) responses to slides of different interest value. The autonomic measures contrasted conditions according to the interest value. This occurred reliably, however, only in conditions in which also a reaction time response should be performed, not in two other variations in which it was not present. Thus the result is not sufficiently clear to suggest that some totally independent role would be addressed to the interest value of an expected event in explaining the anticipatory response to that event.

In the present experiment this question was touched upon only by correlating the response-scores individually with the ´interest´-variable as it is reflected via the unpleasantness rating of each event. This rating did not have any nonzero correlation with any physiological score of anticipatory activity when the computation consisted of the data across conditions. However, pre-S2 responses covaried significantly with this rating in Arithmetic condition in FI-group. Arithmetic task may be interesting or not for the performer and the interest rating would be correlated with the unpleasantness rating. It was found that the more unpleasant (less interesting) the task was experienced as, the larger were the anticipatory skin conductance responses during the first interval (r 0.59) and also, although in less covariant form, during the second interval (r 0.29). A most probable interpretation of this result is that the expected unpleasantness of the required effort or anticipatory fear of failure in the task, rather than anything related to ´interest´, produced this correlation.

The example of the correlation of anticipatory skin conductance responses with unpleasantness-rating leads one to doubt the argument that all response-specificity follows the task-related demands anyway unambiguously. The fact that skin conductance was otherwise not very sensitive to show responsivity during cognitive performances refers to a possibility that the emotional evaluation of the task, which varies between Ss, may have made some own contribution to the response determination in this specific context. This interpretation is supported by the evidence about the special sensitivity of skin conductance on the emotional impacts of the events as demonstrated also in the present study.

A more general further hypothesis would be that the main specificity in the response to any event is based on demands for activity as specified by the task, and variables like ´interest´ or event-related emotional associations might enhance or reduce this basic effect. Indirect evidence to support this contention comes from comparison of the third-interval responsivity of SE-group with that of other groups. The latter had a better opportunity to concentrate on the experimental events and consistently their response patterns were much more specific with respect to the experimental events. In this context a better concept for ´interest´ might be, however, ´involvement´, which includes all the factors making Ss concentrate on an activity as presupposed by the task or presented stimulation.

5.3. Preception

5.3.1. Predictability and arousal: earlier evidence about tonic and phasic effects

The effects of advance information about future events on the physiological reactivity to these events have been studied in terms of predictability (Weiss, 1970), certainty (Grings, 1973) and preception (Lykken, 1959). Weiss has made attempts (1970, 1971) to show that unpredictable aversive events have more noxious effects in the sense that they are more likely to produce physical pathology (ulceration) than the predictable ones. In related experiments subjects experience noxious stimulation so that they either have an opportunity to predict when stimulus is delivered or have no possibility to know when it comes. Predictability is varied by using warning signals with constant ISI or giving the stimulation without warning. The main difference seems to come from the lack of ´safety´ periods in the unpredictable condition which makes the situation continually stressful without any recovery between trials. The effect should thus be examined as a result of tonic rather than phasic stress. This makes the approach of Weiss less interesting for the present purpose.

Recently a new hypothesis has taken shape on the basis of a synthesis of the aforementioned thinking like that of Weiss and of Perkin´s (1968) preparatory adaptive response interpretation of conditioning. It concerns more directly phasic arousal and preactivity. The Perkin´s hypothesis states that the aversiveness of the UCS is reduced as a function of preparation possibility. Proceeding from this kind of thinking it has been assumed that advance information has its effects because it permits preparatory adjustment, initiation of physiological responses (eg. elevation of catecholamines), which prepare the organism to cope physiologically with the ensuing physical stressor (Bassett, Cairncross, & King, 1973; Punch & King, 1976). This formulation renders it possible to demonstrate manifestations of the preparation on the same physiological level where also the beneficial effects, ie. reduced impact of the noxious event, can be explicated. Accordingly, skin conductance response anticipating shock-UCS in long ISI classical conditioning may be assumed to have the adaptive function of preventing skin from the potential injury which a shock-UCS may produce. This can be proved by showing that an anticipatory conductance increase directly affects the impact of the shock as Dengerink and Taylor (1971) have hypothesized.

Quite recently Champion and Hodge (1983) have made an interesting experiment, which seems to support this kind of thinking. They compared the electrodermal responses elicited by constant current shocks to the ones that were elicited by constant voltage shocks. From Ohm´s law they deduced that when the current of electric stimulation between two skin locations is held constant an increase in the skin conductance would result in a decrease in the physical intensity of the stimulus impact. On the other hand, when holding the voltage of stimulation constant the relation should be the opposite. As expected the repeated constant current versus voltage stimulation of the skin was accompanied by an increase and decrease of skin conductance, respectively, according to the shock type so that the physical intensity of the shock was minimized in the skin surface ´interface´. The results seem to be consistent not only with the above deduction but also parallel with each of the three respective assumptions of Perkins, King and his associates and Dengerink & Taylor. The preparatory physiological changes (King) behaved so that the physical intensity (Dengerink & Taylor) and also the experienced aversiveness (Perkins) were minimized, although the last was not quite unequivocally demonstrated.

The results fit with the functionalistic thinking that the anticipatory physiological changes occurring in the periphery prepare the organism for the expected future so that these may also have more global beneficial effects, like a reduction in the experienced aversiveness of the stimulation in this case. This demonstrates that anticipatory activity may have an equally important psychophysiological and biological meaning as the post-stimulus activity has and that these two may also be empirically related.

Some related research has been devoted to the psychological mechanism, viz. how foreknowledge affects psychological variables like preference for unavoidable signalled vs. nonsignalled stimulation (eg. Badia, Suter, & Lewis, 1967) or perceived noxiousness of the so-differing stimulus impacts (eg. Lanzetta & Driscoll, 1966). Both of these claims - which are important from the perspective of Perkin´s theory, but are not necessary implications of the above mentioned interpretation - have proved controversial (Furedy, 1975). These problems are not, however, given further analysis here because they do not immediately touch the present main problem: the effect of foreknowledge on the physiological reactivity to the informed event.

Grings has classified predictability into three elements of event certainties, each of which has been shown to have some separate effect on arousal responsivity. These are event, time and quality certainties, respectively. In the related research the main dependent variable has been the amplitude of the skin conductance response to shock or loud noise. Grings and Sukoneck (1971) and Öhman et al., (1973) have reported effects of event certainty, Elliot (1966) Lykken et al., (1972) and Peeke & Grings (1968) those of time certainty and Epstein & Clark (1970) and Öhman (1971) of quality certainty, respectively. These certainty elements have also been proved to have a cumulating effect on the amplitude of conductance response to aversive noise (Carey & Grings, 1976). Furthermore Lykken et al., (1972) and Schafer et al., (1981) have demonstrated the time certainty effect on evoked potential amplitude to shock and Boddy (1973) to tone. Advance information about various quality features viz. modality (Sutton et al. 1965) and location of stimulus (Butler, 1972) or pitch of auditive stimulus (Ritter et al., 1968; Roth, 1973) have been shown to reduce the evoked potential responses to these stimulations.

5.3.2. Positive and negative preception

Neither Grings nor most of the other mentioned experimenters have been interested in making attempts to explain this phenomenon. David Lykken has taken the task more seriously.

Lykken (1959; Lykken & Tellegen, 1974) has conceptualized a special preception mechanism to describe the realization of the effects of advance information on event-related physiological responses. It may produce a ´positive preception´ effect when predictability makes an organism able to ´tune´ the perceptual system to augment its sensitivity for detection or organisms´readiness for performance. ´Negative preception´ allows a subject to inhibit his arousal response to a noxious or distracting stimulus and thus it attenuates the impact of the stimulus on the organism.

The effects are thought to be based on ´tuning´ of the afferent system via reticular activation modulations, which are reflected in the arousal measures like skin conductance and heart rate. In the case of negative preception these arousal responses are reduced and in the case of positive preception these are expected to be accentuated (Lykken & Tellegen, 1974).

Lykken has construed his hypothesis mainly on the basis of skin conductance and heart rate data. He has not considered specifically how this explanation would help to understand the evoked potential (EP) findings catalogued above. This latter data does not permit a similar logic as that used in interpreting the ANS-results, but the problem is intimately interwoven with preception and thus briefly discussed below.

A different explanation should be given to understand the effects of advance information which reduce EP-amplitudes when the critical stimuli neither are aversive nor threaten the physical integrity of the organism anyway but rather presuppose special attention as the functioning of the positive preception mechanism would do supposedly with the opposite changes in arousal. One explanation might be that prewarning somehow by adding natural redundancy (which evoked potential averaging presupposes) in the informational input results in a decrease in arousal. Schafer and Russel (1981) have spent effort to verify that the effect neither results from differential general arousal level, habituation nor from selective attention, the most common correlates of evoked potential responses. It also seems to be proven that these effects cannot be explained as a result of differences in experienced stimulus intensity, because the evoked potential changes do not match with this type of effects. This latter explanation would come nearest to Lykken´s interpretation (ie. warning affects via reticular influences on the afferent system).

To follow the Lykken´s hypothesis the effect should be phasic in nature and the direction of the change dependent on the purpose of the activity (ie. enchancement versus attenuation of the stimulus input). In the evoked potential experiments the last variable has not been explicitly varied. Lykken´s theory seems to offer no direct interpretation of this general reduction of EP-amplitudes. Schafer and Russel (1981) are ready to argue that these evoked potential results prove that the mere ´cognitive act of knowing when the stimulus will occur attenuates the evoked potential amplitude´ and reflects ´the influence of cognitive factors upon electrophysiological activity´. Thus the reduction of the physiological responses to an event produced by the prewarning may represent a broader and more complicated phenomenon than that concerned with the ´negative preception´ explanation of Lykken.

Before examining the implications of present results related to preception, a short summary repetition of the findings most directly related to the main argument is called for. These concern the context and manifestations of negative preception, which appear in electrodermal responses to warned shocks. The predictability was varied here in two main steps: via mere quality certainty with temporal certainty held constant (main comparison: NI- vs. FI-group) or via quality and temporal certainty (SE- vs. FI-group). SE-FI-contrast includes a larger difference in terms of predictability and should thus display a larger difference.

The resulting main differences were clearly in line with the expectation. Both noninformed groups had higher means than FI-group in shock condition. The results parallel Lykken´s hypothesis and are also partially in agreement with the further specification of Carey and Grings that the uncertainties tend to have additive effects on the amplitudes of skin conductance. This latter appeared, however, only in the fact that the quality uncertainty effect appeared only in the shock condition while when also temporal uncertainty was present in both Stimulus conditions.

5.3.3. Preception and conditioning

The main evidence and discussion concerning preception has been based on the negative preception effect. The hypotheses concerning physiological arousal manifestations of positive preception are speculative and no direct empirical evidence exists for their support. Also the evidence about negative preception is restricted to the use of shock or loud tone/noise as the critical event and skin conductance or heart rate as the critical arousal response. The negative preception effect as it appears in this research is empirically closely associated with results demonstrating the so-called UCS-diminution effect in conditioning research (Kimmel, 1966). This phenomenon appears as a decrease of UCR amplitude to the typical UCS (shock and tone) as a function of repeated pairing of UCS and CS. Kimmel (1966) considers it as an important, adaptive and automatic product of conditioning. This interpretation differs from the view of Lykken and Tellegen (1974) about preception although the concrete manifestations of both of them are exactly the same. They consider preception to be a phenomenon controlled on the higher level of the ´second signal system´, presupposing voluntary attention and awareness. (In terms of conditioning they think it may, however, be related to something which Grings (1973) has conceptualized as ´cognitive conditioning´). They argue that preception is not controlled by conditioning or habituation-like mechanisms.

An essential feature which Lykken and Tellegen introduce to support their contention is that preception presupposes effort and varies as a function of it. This argument is open to empirical testing. Because no earlier evidence exists and the present experimental paradigm allows a partial test, the related results are discussed as the first implication of the present findings to preception research.

(1) **Effort and preception effect.** In the present experimental paradigm shock and loud tone represented critical events which have been the only stimuli used in the autonomic preception experiments so far. These two have, however, never earlier been used simultaneously to allow comparison. Post-experimental ratings revealed that shock was experienced to be more unpleasant than tone. Thus presumably the informed subjects were less involved in the preparation for tone-Stimulus and offered less ´effort´ for coping with it than with the shock. Consistent with this expectation the shock-condition was both anticipated with larger responses than tone (and thus apparently with larger effort) and the shock also ´elicited´ responses

of clearly smaller relative amplitude in Fully Informed group. No significant difference was found between informed and noninformed groups in electrodermal response to S2-tone. The results are thus in line of Lykken´s interpretation of the response attenuation as a phenomenon whose existence is dependent on the subject´s involvement in the events. These can also be taken as evidence for Lykken´s argument that preception does not follow any ´primitive´ noncognitive conditioning mechanism and cannot be identical with the UCR-diminution effect proposed by Kimmel.

The present findings offer a further result, which may be seen to support Lykken´s preception interpretation as contrasted with the conditioning one. The course of response modification failed to match the expected course of CRs. This is discussed below in the context of the third (3) implication.

5.3.4. Preception effect, response interference and certainty manipulation

Furedy (1970) and Furedy & Klajner (1974) have suggested alternative explanations for preception. One is that the smaller responses to signalled unconditioned stimuli are merely due to effector fatigue resulting from the response to the warning signal. The validity of this proposition has been tested in two earlier studies by varying the temporal uncertainty and holding the mean ISI constant or varying it systematically to control for the possible response interference effect. In the first one of these (Peeke & Grings, 1968) the certainty-manipulation consisted of the use of a warning signal of either a fixed 5.5 sec. or a random duration before the Shock stimulus. The means of the ISIs in the two comparison conditions were held constant and the responses to shock were compared. In the other study (Waid, 1979) the warnings of four ISI durations consisted of the comparison conditions for trials delivered without a warning signal. In both experiments the amplitudes were consistently lower in the more predictable conditions. Furthermore in the second study (Waid, 1979) the ISI duration was shown to be linearly related to the SCR decrease to noise stimulus in 0- to 11-sec. warning trials. This strongly supports a contention that response interference does not explain the related response reduction. The results reveal that the more certain the subject can be about the delivery of the event the less is its response producing potential. This idea is central to the preception ´theory´, whose empirical support is restricted to this temporal certainty aspect. The present data permits testing a generalization in which the certainty manipulations is not based merely on a time variable.

In the present study also quality- rather than merely temporal certainty-was varied. In fact effects of the first consisted the main interest. This comparison type allows both a new method to control the response interference factor and also a theoretically differentiable way to manipulate the certainty and to examine the determinants of preception. This is discussed as the second implication of the present findings for the study of preception.

(2) **Response interference and certainty manipulation.** The effects of advance information were tested in constant ISI conditions by varying the foreknowlege about the event type to be delivered as S2 (ie. quality certainty in FI - NI -comparison). Also the combined quality and temporal certainty condition (ie. total certainty) could be compared with the condition in which Ss could know neither the event which would come next nor the time when the next event (S1 or S2) will come (in FI - SE -comparison). The first comparison permitted an explicit control of response interference. Both of the comparisons allow evidence about a new type of certainty manipulation.

Both Noninformed and Fully Informed groups experienced S1-S2 in fixed intervals and thus the possibility of response interference was held equal. FI-group had event quality information in S1 which made the critical difference in the predictability of the events. It may be speculated that holding the ISI constant does not suffice to control all possible response interference because the unequal warning stimulus contents in the groups produce different first-interval responses. Amplitudes varied considerably between groups in skin conductance. Responses to the shock label were larger in the Fully Informed group. Because of an 8.8 sec. ISI it is not, however, likely that the S1-elicited response could have interfered with the S2-response. The second-interval responses may have participated in such confounding, but mean amplitudes did not show differences between groups in responses immediately preceding the shock.

Overall it seems that the S1-elicited responses, which Furedy thinks are critical, could not have interfered with the S2-responses. The role of the anticipatory response is more difficult, when the question is viewed from an other perspective. It might be considered to belong as a central component to the mechanism which produces the response reduction according to the views expressed by King and his associates and Dengerink & Taylor. Even when taken for granted that also an anticipatory response component may have its effect on S2-response technically via a response overlap, the data seems not to support an interference interpretation. If the S2-response is scored from the baseline preceding the anticipatory response, the critical difference between S2-responses between informed and noninformed groups seems not to disappear. This can be proved by comparing the relative amplitudes of these two response components (see Figure 2B and 2C). The contrast in the third-interval response is too large to be explained via a mere interference effect from anticipatory responses.

5.3.5. Preception, habituation and conditioning

The second alternative interpretation of the preception effect identifies it with habituation of the orienting reflex (Furedy & Klajner, 1974). This explanation seems to fit well with the data of experiments in which random and fixed ISI conditions are used to manipulate the certainty temporally. Accordingly the less predictable events given in random WS-UCS ISI can be expected to elicit more probably OR or OR reinstatements. At the same time the responses produced by the predictable stimulus should display habituation to create a difference between these two conditions. The last presupposition (ie. habituation in the warned group) is especially critical. Lykken et al., (1972) have, however, shown that the preception effect can be demonstrated even when no diminution over repeated trials occurs (presumably - Lykken does not specify - because the effect is immediate, ie. evident from the very first trials). Consequently Lykken considers preception to be a distinct process playing a role complementary to that of habituation.

A main difference might be an implicit anticipatory initiation of the processes responsible for the reduction of the response amplitudes in preception but not in habituation. Preception may be expected to have anticipatory physiological manifestations too. These two forms of manifestation have been shown to result both in preception and conditioning settings, ie. as an anticipatory response/conditioned response and response reduction via preception/UCR diminution. An empirical way to show conditioning as insufficient to explain the preception-related responses is to prove that the development of the related response components in a preception condition do not fit together with those peculiar to conditioning.

No one has argued that preception requires similar advance experience of stimulus pairing as is thought to be needed for conditioning. Thus the preception-reduction of the response should be visible from the very first advance-informed presentations of the critical stimulus. As far as I know there is no earlier published evidence of this. The present procedure offers data which is relevant for contrasting preception both with habituation and conditioning. These are discussed as the third preception related implication (see below).

(3) **Habituation, conditioning and preception effect.** The unwarned stimuli are hypothesized to elicit responses less suggestible to habituation than responses to warned stimuli. The present habituation data revealed no interaction between groups and trial repetition which could be interpreted to result in differences expected on the basis of a negative preception hypothesis.

Examination of the tonic levels, however, revealed a decrease in skin conductance as a function of advance information (see Fig. 1A). Also the level of pulse amplitude constriction showed some tendency towards this (see Fig. 3). No phasic variable revealed parallel development which would allow a conclusion that there were some consistent differences in the trial-related change of ′general arousal′ between groups.

Because preception is supposedly a phasic phenomenon and no evidence about differential habituation in the phasic response could be discerned, the present data fail to support the interpretation which reduces preception to habituation. Habituation on the tonic level and preception seem, however, to manifest a complementary function for adaptive behavior.

Inspection of the trial effects in phasic responsivity fails also to reveal evidence to support a conditioning-like development of response amplitudes either in anticipatory or in third-interval responses. Both the anticipatory responses to the shock and the reduction of the shock-elicited responses were visible from the very first trial. This finding is inconsistent with the expected slow development of CR and UCR-diminution, which verifiably presupposes more trials (Kimmel & Pennypacker, 1962; Kimmel, 1966). Especially the first-interval response revealed simple main effects of trials. These were, however, always to the direction of decrease and thus inconsistent with conditioning. The anticipatory responses did not increase in any variable or condition as would be expected on the basis of the conditioning hypothesis. The third-interval response showed reduction as a function of trials in skin conductance, but no interaction with groups was found to support the response-diminution interpretation. Thus it is possible to conclude that conditioning in its classical form cannot explain the preception-type modification of the third-interval autonomic responses in the present data.

5.3.6. Positive preception and arousal

It is a well known fact that reaction time performance becomes more efficient when the imperative stimulus is preceded by a warning stimulus. Treisman and Howarth (1959) have shown that signals are detected better when presented with a prewarning. Especially this latter finding has been taken to support a contention that there also exists a positive preception which accentuates rather than attenuates the sensory intake (Lykken & Tellegen, 1974).

The direct evidence about related physiological responses to warned vs. unwarned events is scanty. Probably the only available evidence comes from Cacioppo and Sandman (1978). They have reported an accentuation of heart rate pattern to a cognitive task presented with a warning signal compared to an unwarned presentation. The present data allow a more detailed verification of the positive preception effect as it is related to the presumed physiological changes. It is discussed as the fourth (4) related empirical implication.

(4) **Positive preception.** The present experimental procedure included three types of relevant tasks (sensory discrimination, mental arithmetic and memory tasks). A demonstration of the positive preception effect on the autonomic-somatic arousal domain would presuppose evidence about more pronounced activity in the informed groups compared to the noninformed ones. Examination of the univariate results indicate that heart rate (especially the peak-measure) behaves as predicted: all three cognitive conditions were accompanied by larger acceleration in the Fully Informed groups than in the Sensitization group. The means of Noninformed group did not, however, differ from those of Fully Informed group.

There were two other measures which revealed significant differences between the critical groups. One was the frontal EMG. Its decreases were in all cognitive conditions more probable in the informed than in the noninformed groups. The largest difference prevailed between FI- and SE-groups. Again no significant contrast could be found between FI- and NI-groups. Some tendency to FI-SE-contrast appeared also in the orbicularis oris EMG-increase measure. FI-group had a significantly larger mean than SE-group in Memory condition.

The only difference which can be expected on the basis of the earlier evidence is the HR-effect, which is in line with Lykken´s hypothesis and the findings of Cacioppo and Sandman. The present findings can be taken as additional proof for concluding that HR tends to show larger acceleration during a task requiring effective processing if the task is predictable than when it is not. However, the certainty should be varied effectively to find this heart rate effect. The event quality-certainty singly did not suffice to manifest this effect as difference from Ss who could predict the mere time of the task delivery. In this connection the temporal uncertainty made the main contribution in producing the differential responses in HR. It was also the common factor in both the present and Kaiser & Sandman´s study.

Subjects have no possibility to time their performances optimally if tasks are delivered without warning. The result might thus also appear in the lowered synchrony of the HR changes. Compatible with this interpretation the peak amplitudes were more prone to show the critical difference than the mean scores of the third-interval HR. However, the total effect was so large that it is not reducible to a difference in the mere synchrony of the HR-responses.

A probable additional explanation comes from differential involvement of subjects, resulting from a less motivating presentation of the tasks to Sensitization group. It may have affected the effort they made to do their best in concentrating on the tasks. This difference is, however, something which is closely related to the preception effect itself. Lykken explicitly predicts that a prewarning increases the effectivity of the task performance when the task has a positive value for the subject.

The other significant differences are more problematic. Why should EMG-responses be reduced or EMG-decreases be more probable in tasks requiring effort when the tasks are prewarned than when these are not? Might it be that Ss become more able to inhibit superfluous activity during effortful execution when warning allows preparation for it? The results are not directly predictable on the basis of Lykken´s formulation of the preception mechanism, but such an interpretation may be in line with his general idea that a warning allows ´tuning´ of the total functioning of the organism to respond to the situational demands.

5.3.7. Preception and stress

Lykken & Tellegen (1974) expect that the preception effect should appear also in other than skin conductance and heart rate indicators of arousal or stress. Thus far no research has been done to test this proposal. This is the fifth aspect to which the present study may give a contribution.

(5) **Preception and arousal changes.** From the nine measures of the present study at least three, viz. pulse amplitude constriction, frontal EMG and respiratory disturbances, can be seen as typical measures of stress, tension or anxiety. Pulse amplitude constriction displayed some tendency to be larger in the noninformed than in the less informed groups, but this achieved significance only in PI-NI contrast. Respiratory disturbances offer one of the most apparent indices of startle response, which an unexpected and sudden stimulus tends to elicit. Surprisingly, it has not been measured in the earlier preception experiments. Here it was consistently shown to display the expected difference between the informed and the noninformed groups. When the effect of respiratory variables were separated from the contrast, the group difference did not, however, disappear. Thus the other measures are not likely to reflect only some potentially secondary effect of respiratory change.

Also the frontal EMG scores (decrease and increase) revealed a difference between the critical groups. Skin conductance and frontal EMG together explained 70 % of the variance included in the NI-FI-contrast, while the maximal explanation achieved by adding the respiratory and the heart rate measures was 88 % in the data for shock-Stimulus condition. The same variables explained 82 % of the contrasts between the three critical groups (FI vs. NI and FI vs. SE).

It must be added that in the present data heart rate did not manifest any negative preception effect. One explanation may be that the use of a clearly less aversive shock than used in the earlier studies faded the HR-effect. The sensitivity of the other measures was apparently better in reflecting the effect of foreknowledge on the response to aversive event. However, on the other hand heart rate displayed changes which most consistently matched with the expected positive preception effect. Furthermore it was not totally neutral even in the negative preception pattern. It made a clear contribution to the multivariate contrast between the critical groups.

The evidence above makes it possible to conclude that skin conductance, respiratory changes and frontal EMG-responses and partially also heart rate behaved as could be predicted on the basis of Lykken's preception hypothesis. Present findings support the contention that preception phenomenon may explain some 'stress reduction' effects as these appear also in physiological reactions other than in skin conductance.

It is worth noting that under the present experimental conditions surprisingly similar response reductions were found also in Motor condition. Thus it may be that the so called negative preception effect is not specifically related to aversive stimulation, but appears also when some effort-consuming motor response should be made (instead of experiencing an aversive stimulus). One interpretation might be that the warning permitted a more controlled performance so that superfluous ´arousal´ was reduced out of the needed manipulation of the response device. The main preception variables of our study, viz. skin conductance and respiratory disturbances, both showed decrease in the informed subjects during the motor performance which is consistent with this interpretation.

Each of the relevant variables made clear individual contributions to the multivariate contrast between the critical groups. This shows that these variables did not represent mere redundant variance. This makes it even more important to include more than one variable in the psychophysiological study of preception. The value of the multivariable approach in psychophysiology turns out thus to be central finding, which seems to be true independent of what phenomenon - arousal, anticipation or preception - is as the main object of interest.

6. GENERAL CONCLUSIONS

The ANS-SNS patterns were hypothesized (H) to display specificity according to the situational requirements both in the post-event responses (H1) and in anticipation (H2) to the event about which sufficient information is available.

The results support the hypotheses. They show that the ANS-SNS patterns of Motor and Cognitive conditions are realiably different from each other and from the patterns related to Stimulus events during both of the critical periods. Also, the responses preceding and following shock-Stimulus could be successfully differentiated from all of the other conditions using multivariable data. The two other sensory conditions (tone-Stimulus and Sensory discrimination task) did not offer as unambiguous a context for explicating clear event-specific response patterns.

The specificity of the anticipatory patterns reliably increased as a function of advance information. This lends support to the second (H2) hypothesis. Already the immediate response to the information about the critical event showed a marked degree of specificity. Only two variables from the nine possible displayed reliable concomitant habituation with this first response component. These two findings together allow a conclusion that an orienting reflex (OR) cannot be differentiated in a two-stimulus condition from anticipatory responses on the basis of mere temporal criteria. If its temporal position as the immediate response to the warning stimulus makes it an OR then the OR is not a nonspecific response. Many of the physiological manifestations following this stimulus immediately reflected almost as clear specificity related to the expected event than did the later pre-event responses.

The pre- and post-event patterns were hypothesized to resemble each other (H3). The physiological patterns preceding each critical event and the related typology of event-response interrelationships of the most informed group were similar to those revealed by the post-event responses. In most comparisons the ordering of the response amplitudes or probabilities were exactly the same. Only exceptions with minor significance were found. So the findings were quite consistently in line with the hypothesis (H3) and permit a preliminary conclusion that the pre-event activity reflects preparation which is with respect of the form of its physiological response profiles related to the event-produced ANS-SNS patterns. Thus the main argument concerning the nature of ANS-SNS activity as a measure and reflector of not only the already realized situational demands but also demands of the immediate future - as specified by its cognitive extrapolation - achieved support.

A further concern was the effect of the opportunity for preparation on the ANS-SNS responses produced by the events itself (H4). The advance information was shown to have varied manifestations. The most reliable was the effect specified in the negative preception hypothesis. The related manifestations were shown to be more extensive within the ANS-SNS domain than has been demonstrated earlier.

The present data did not lend support to an interpretation that the response-reduction effect of advance information can be explained directly via conditioning or habituation. Rather they lead to the likely conclusion that more cognitive processes are involved.

Advance information was shown to also have other manifestations than those predictable on the basis of the negative preception hypothesis. These were, however, too complex to permit any unambiguous conclusions without additional research.

TIIVISTELMÄ: ANTISIPAATION JA VIRIÄMISEN PSYKOFYSIOLOGIA

Tutkimus kohdistuu psykofysiologian teoreettisiin ja empiirisiin perusteisiin. Lähtökohtana on kritiikki, joka suuntautuu psykofysiologiassa yleiseen pyrkimykseen redusoida fysiologisista muuttujista eristettävä, psykologisesti relevanttina pidetty tieto yksidimensioiseen aktivaatiokäsitteeseen ja psykofysiologiset mittaukset ärsykkeiden virittämiin välittömiin reaktioihin. Tutkimuksen tavoitteena on osoittaa aktivaatioilmiöiden ja erityisesti autonomisen ja somaattisen hermostojärjestelmän faasisen reagoinnin monitasoisuus ja monidimensioinen luonne. Samoin pyritään osoittamaan tämän fysiologisen aktiivisuuden psykologinen relevanssi paitsi parhaillaan realisoituvan tapahtuman virittämien toimintavaatimusten tapahtuma-spesifinä heijastajana myös tuon tapahtuman ennakoinnin ja/tai siihen valmistautumisen spesifinä ilmaisijana. Viimemainittua tutkitaan antisipaation käsitteen avulla. Sen psykofysiologiset ilmenemismuodot autonomisen ja somaattisen hermostojärjestelmän tasolla ovat erityisen huomion kohteina.

Viriämistoimintoja, niiden tasoja, modifioitumista ja lähteitä sekä autonomisen hermoston funktioita koskevan ja antisipaation kannalta keskeisen teoreettisen ja empiirisen tiedon tarkastelun perusteella asetetaan seuraavat hypoteesit ja ongelmat:

Hypoteesi 1. Autonomisen (ANS) ja somaattisen (SNS) hermostojärjestelmän faasiset vastemallit ilmentävät laadullista tapahtumaspesifisyyttä. Tätä spesifisyyttä selvitetään hahmottamalla reaktiomallien muotoutumista sensoristen, kognitiivisten ja motoristen tehtävien sekä ärsyketilanteiden yhteydessä.

Hypoteesi 2. Jo tapahtumaa edeltävät ANS-SNS-muutokset osoittavat spesifisyyttä, ja se lisääntyy kh:n käytettävissä olevan, tapahtumaa koskevan ennakkotiedon funktiona. Tapahtumaa edeltäviä muutoksia tarkastellaan orientoitumisen ja antisipaation käsitteiden näkökulmista erittelemällä missä määrin välitöntä reaktiota ennakkoinformaatioon voidaan tulkita nonspesifinä orientiotumisreaktiona ja myöhempiä, kriittistä tapahtumaa välittömästi edeltäviä muutoksia, siitä poikkeavina antisipatorisina reaktioina.

Hypoteesi 3. Tapahtumaa edeltävät fysiologiset muutokset muistuttavat tapahtumien sinänsä virittämiä vastemalleja henkilöillä, joilla on antisipoinnin mahdollistavaa ennakkotietoa riittävästi käytettävissä.

Hypoteesi 4. Ennakkoinformaatio vaikuttaa myös tapahtuman itsensä vi-

rittämään fysiologiseen reagointiin tilanteen mukaan, mutta etenkin vaimentaen aversiivisen ärsykkeen tuottamaa reagointia ns. negatiivisen prekeptiohypoteesin (negative preception) ilmaisemassa muodossa.

Hypoteesien testaus perustuu kokeisiin, joihin osallistui 112 koehenkilöä. Niissä rekisteröitiin yhteensä yhdeksää fysiologista 'kanavaa'. Ne olivat ihon konduktanssi, sydämen syketaajuus, hengitys, pulssiamplitudi, veren voluumi, pupillin dilaatio (vain osa-aineistolla) sekä fleksorista, frontaaliksesta ja orbicularis oriksesta mitattu EMG- aktiviteetti. Kutakin kanavaa koskevat mittaukset kvantifioitiin tarvittaessa useammalla muuttujalla.

Mittauksia tehtiin kuudessa tilanteessa, joista kukin sisälsi yhden 'tapahtuman'. Niistä kaksi oli kognitiivisia tehtäviä (päässälasku ja muistitehtävä), yksi sensorinen ja yksi motorinen tehtävä sekä kaksi sensorista ärsyketilannetta (auditiivinen ja somatosensorinen). Tapahtumia esitettiin kvasisatunnaisessa järjestyksessä neljälle koehenkilöryhmälle. Ryhmät erosivat sen suhteen missä määrin ne saivat ennakkotietoa kriittisestä tapahtumasta. Yksi ryhmistä sai sekä tapahtuman sisältöä että sen ajankohtaa koskevan tiedon. Toinen ryhmä vain vihjeen sisällöstä aikainformaation lisäksi. Kolmas ryhmä pelkän aikainformaation ja viimeinen ei lainkaan ennakkotietoa. Kolmelle ensinmainitulla ryhmälle ennakkotieto annettiin 8.8 sekuntia tapahtumaa edeltävässä visuaalisessa ärsykkeessä. Neljäs ryhmä koki samat ennakkotietoärsykkeet ja tapahtumaärsykkeet toisistaan riippumattomassa järjestyksessä. Fysiologisten mittausten tarkastelussa keskityttiin lähinnä kolmen reaktiointervallin tarkasteluun. Ensimmäisellä ilmeni ennakkoinformaation herättämä välitön reaktio, toinen sijoittui välittömästi kriittistä tapahtumaa edeltävään ajankohtaan ja kolmannen intervallin aikana voitiin kvantifioida tapahtuman sinänsä virittämä faasinen reaktio. Kukin 'mittausikkuna' oli n. 4 sekunnin kestoinen riippuen mitattavan reaktion latenssipiirteistä. Lisäksi mitattiin tehtävien suoritustasoa sekä koottiin tietoa subjektiivisista, koetapahtumia koskevista tuntemuksista.

Kaikki kuusi koetilannetta voitiin erottaa tilastollisin menetelmin toisistaan käytettäessä erotteluperusteena koko fysiologisen muuttujajoukon antamaa tietoa samanaikaisesti. Silti päätilannetyyppejä so. kognitiivisia, ja motorisia tehtäviä sekä sensorista ärsytystä koskevat kontrastit olivat selvästi näiden päätyyppien sisäisiä tilanne-eroja selvemmät. Havaintojen selittäminen yksidimensioisella aktivaatiomallilla ei osoittautunut mahdolliseksi tarkasteltiinpa sitä pääkomponenttianalyysin keinoin tai vertailemalla eri tilanteiden virittämien yksittäisten reaktioamplituudien suuruusjärjestyksiä. Näin ensimmäinen hypoteesi sai tukea.

Samankaltainen tilannespesifisyys kävi ilmi jo tapahtumaa ennakoivissa reaktiomalleissa. Niissä ilmenevät tilanteiden väliset multivariaattiset kontrastit olivat lähes yhtä selvät kuin tapahtumien sinänsä virittämien reaktiomallien välillä havaitut. Spesifisyys lisääntyi merkittävästi ennakkoinformaation funktiona ja ´esiaktiivisuus´ mahdollisti tilanteiden erottelun tapahtumasta ja sen ajankohdasta ennakkoon informoidulla ryhmällä lähes yhtä suurella tarkkuudella kuin tapahtuman jälkeisetkin reaktiot. Näin myös toinen hypoteesi sai tukea.

Spesifisyys ilmeni jo ennakkoinformaation virittämissä välittömissä reaktioissa, mikä osoittaa, ettei niitä voida pitää ns. nonspesifeinä orientoitumisreaktioina, vaan ne jo osoittavat antisipatorisen, tulevaan tapahtumaan spesifisti valmistavan reaktion ominaispiirteitä.

Tapahtumaa edeltävät reaktiomallit muistuttivat huomattavasti tapahtuman sinänsä virittämiä reaktiomalleja, vaikka joitakin yksittäisiä poikkeamia havaittiinkin. Näin myös kolmas hypoteesi sai, tosin varauksin, tukea.

Prekeptiota koskevat havainnot toistivat suhteellisen johdonmukaisesti aiemmin saatuja tuloksia siitä, että ennakkoinformaatio vaimentaa voimakkaan sensorisen ärsytyksen virittämiä reaktiota ja tämä ilmenee erityisesti ihokonduktanssissa. Tämän lisäksi voitiin havaita vaikutuksia myös sellaisissa fysiologisissa reaktioissa, kuten frontaali-EMG:ssä ja hengityksessä, joista ei ole ollut aiempaa tietoa. Prekeptio-ilmiön psykofysiologista ilmenemistä pystyttiin alustavasti täydentämään monella yksityiskohdalla, joiden osalta päätelmät kuitenkin edellyttävät replikointia.

Kaikenkaikkiaan koesarja tuotti todistusaineistoa siitä, että fysiologisista reaktiomalleista voidaan erottaa luotettavasti ainakin kolme tilannevaatimuksien mukaisesti muotoutuvaa reaktiomallia niin, että tapahtumien ollessa ennakoitavissa ne ilmenevät samankaltaisina sekä antisipaation että suorituksen /kokemisen aikana. Samoin ennakkotiedon saatavuudella voitiin osoittaa olevan vaikutusta myös itse tapahtumien virittämiin fysiologisiin reaktioihin. Näin psykofysiologisten muutosten tarkastelun voitiin osoittaa edellyttävän lähestymistä, joissa muutoksia ei tarkastella ärsykkeen tuottamina välittöminä reaktioina, vaan aktiviteettina, joka heijastaa yhtälailla henkilön orietoitumista välittömään tulevaisuuteen, tavoitteellista suuntautumista.

Tutkimuksessa tarkasteltiin myös fysiologisen reagoinnin ja suoritustason sekä tapahtumien subjektiivisen kokemisen korrelaatioita lähinnä fysiologisten muutosten tulkinnan eräinä apuneuvoina. Niiden yhteydessä ilmeni kuitenkin myös sinällänsä kiinnostavia seikkoja. Mielenkiintoisimpia olivat mm. havainnot, jotka osoittivat eri fysiologisten muuttujien kovarioivan varsin eri tavoin kokemus- ja suoritustasoa ilmaisevien muuttujien kanssa. Tarkastelu ei em. tavoitteensakaan vuoksi mahdollista kuitenkaan yleistettävissä olevien päätelmien esittämistä ko. yhteyksistä. Ne edellyttävät koetulosten replikointia.

Pohdiskeluosassa tuloksia tarkastellaan yksityiskohtaisesti olemassaolevaan aikaisempaan tietoon nivoen. Aiempi tieto on suhteellisen niukkaa ja epäsystemaattista. Saadut tulokset antavat mahdollisuuksia sen integrointiin ja psykofysiologisen tarkastelun soveltamiseen eräisiin psykologisen tutkimuksen ajankohtaisiin kysymyksiin.

REFERENCES

Adamowicz, J.K. & Gibson, D. (1972) Verbalization, cognitive effort and HR alteration. *Canadian Journal of Psychology,* 26, 1, 1-10.

Ahonen, T., Lyytinen, H., Partanen, T. & Pietiläinen, R. (1977) Pattern of phasic arousal related to variation in cognitive effort with special reference to speech organ EMG and age effects. Reports from the Department of Psychology, University of Jyväskylä, 199.

Allport, F.H. (1955) *Theories of perception and the concept of structure.* New York: Wiley.

Anastasiades, P. & Carrol, D. (1978) The behavioural significance of heart rate: The Lacey´s hypothesis. *Biological Psychology,* 7, 249-275.

Andreassi, J.L. (1980) *Psychophysiology.* New York: Oxford University Press.

Andrew, R.J. (1974) Arousal and the causation of behavior. *Behaviour,* 51, 3-4, 135-165.

Anokhin, P.K. (1974) *Biology and neurophysiology of the conditioned reflex and its role in adaptive behaviour.* Oxford: Pergamon Press.

Atkinson, J.W. (1964) *An introduction to motivation.* New York: D. van Nostrand Company, Inc.

Averill, J.R. (1973) Personal control over aversive stimuli and its relationship to stress. *Psychological Bulletin,* 80, 286-303.

Badia, P., Suter, S. & Lewis, P. (1967) Preference for warned shock: Information and/or preparation. *Psychological Reports,* 20, 271-274.

Bankart, C.P. & Elliott, R. (1974) Heart rate and skin conductance in anticipation of shocks with varying probability of occurrence. *Psychophysiology,* 11, 160-174.

Barry, R.J. (1979) A factor-analytic examination of the unitary or concept, *Biological Psychology,* 8, 161-178.

Bartlett, F.C. (1932) *Remembering: A study in experimental and social psychology.* Cambridge, England: University Press.

Bassett, J.R., Cairncross, K.D. & King, M.G. (1973) Parameters of novelty, shock predictability and response contingency in corticosterone release in the rat. Physiological Behavior, 10, 901-907.

Beatty, J. (1982) Task-evoked pupillary responses, processing load, and the structure of processing resources. Psychological Bulletin, 91, 2, 276-292.

Beatty, J. & Wagoner, B. (1978) Pupillömetric signs of brain activation vary with level of cognitive processing. Science, 199, 1216-1218.

Berlyne, D.E. (1967) Arousal and reinforcement. Nebraska Symposium of Motivation, 15, 1-110.

Birbaumer, N., Elbert, T., Lutzenberger, W., Rockstroh, B. & Schwarz, J. (1981) EEG and slow cortical potentials in anticipation of mental tasks with different hemispheric involvement. Biological Psychology, 13, 251-260.

Blaylock, B. (1972) Some antecedents of directional fractionation: Effects of "intake-rejection", verbalization requirements, and threat of shock on heart rate and skin conductance. Psychophysiology, 9, 1, 40-52.

Boddy, J. (1973) Evoked potentials in reaction time with a variable foreperiod. Quarterly Journal of Experimental Psychology, 25, 323-334.

Bohlin, G. & Kjellberg, A. (1980) Orienting activity in two-stimuli paradigms as reflected in heart rate. In H.D. Kimmel, E.H. van Olst & J.F. Orlebeke (Eds.) The orienting reflex in humans. Hillsdale: Lawrence Erlbaum.

Bower, A.C. & Tate, D.L. (1976) Cardiovascular and skin conductance correlates of a fixed foreperiod reaction time task in retarded and nonretarded youth. Psychophysiology, 13, 1, 1-9.

Brener, J. (1974) A general model of voluntary control applied to the phenomena of learned cardiovascular change. In P.A. Obrist, A. H. Black, J. Brewer & L.V. Dicara (Eds.) Cardiovascular Psychophysiology. Chicago: Aldine.

Brewer, W.F. (1974) There is no convincing evidence for operant or classical conditioning in adult humans. In W.B. Weimer and D.S. Palermo (Eds.) Cognition and the symbolic processes. Hillsdale: Lawrence Erlbaum.

Bridger, W.H. & Mandel, I.J. (1964) A comparison of GSR responses produced by threat and electric shock. Journal of Psychiatrical Research, 2, 31.

Broadbent, D.E. (1969) Stimulus set and response set: Two kinds of selective attention. In D.I. Mostofsky (Ed.) Attention: Contemporary theory and analysis. New York: Appleton-Century-Crofts.

Brooks, C. (1979) New advances and the predictable future. In: C. Brooks, K. Koizumi & A. Sato (Eds.) Intergrative functions of the autonomic nervous system. Amsterdam: Elsevier.

Brooks, C. Koizumi, K. & Sato, A. (1979) Intergrative functions of the autonomic nervous system. Amsterdam: Elsevier.

Bruner, J.S. (1957) On perceptual readiness. Psychological Review, 64, 123-152.

Bruner, J.S. & Postman, L. (1947) Tension and tension release as organizing factors in perception. Journal of Personality, 15, 300-308.

Bruner, J.S. & Postman, L. (1949) Perception, cognition and behaviour. Journal of Personality, 18, 14-31.

Butler, R.A. (1972) The influence of spatial separation of sound source on the auditory evoked response. Neuropsychologia, 10, 219-225.

Buzard, D., & Cowings, P. & Miller, N. E. (1975) Visceral responses to opposite types of autogenic-training imagery. Biological Psychology, 3, 49-55.

Cacioppo, J.T. & Petty, R.E. (1974) Lip and nonpreferred forearm EMG activity as a function of orienting task. Biological Psychology, 9, 109-119.

Cacioppo, J.T., Petty, R., Snyder, C. & Quintanar, L. (1979a) Changes in cardiac and facial EMG activity during the forewarning, anticipation and presentation of proattitudinal, counterattitudinal and neutral communications. SPR Abstracts 1978, (8b). Psychophysiology, 16, 2, 194.

Cacioppo, J.T. & Petty, R.E. (1979b) Attitudes and cognitive response: an electrophysiological approach. Journal of Personality and Social Psychology, 37, 12, 2181-2199.

Cacioppo, J.T. & Petty, R.E. (1981) Electromyographic specificity during covert information processing. Psychophysiology, 18, 5, 518-523.

Cacioppo, J.T. & Sandman, C.A. (1978) Physiological differentiation of sensory and cognitive tasks as a function of warning, processing demands, and reported unpleasantness. Biological Psychology, 6, 181-192.

Campos, J.J. & Johnson, H.J. (1966) The effects of verbalization instructions and visual attention on heart rate and skin conductance. Psychophysiology, 2, 305-310.

Campos, J.J. & Johnson, H.J. (1967) Affect, verbalization, and directional fractionation of autonomic response. Psychophysiology, 3, 285-290.

Carey, C.A. & Grings, W.W. (1976) The effects of time, event and quality certainty on electrodermal response magnitude to CS and UCS. Bulletin of the Psychonomic Society, 7, 3, 321-323.

Carroll, D., Marzillier, J.S. & Merian, S. (1982) Psychophysiological changes accompanying different types of arousing and relaxing imagery. Psychophysiology, 19, 1, 75-82.

Carroll, D., Marzillier, J.S. & Watson, F. (1980) Heart rate and selfreport changes accompanying different types of relaxing imagery. Behaviour Research & Therapy, 18, 273-279.

Cattel, R.B. & Scheier, I.H. (1961) The meaning and measurement of neuroticism and anxiety. New York: Ronald Press.

Champion, R.A. & Hodge, R. (1983) The application of the preparatoryresponse hypothesis to changes in basal skin resistance. Psychophysiology, 20, 1, 59-62.

Chase, W.G., Graham, F.D. & Graham, D.T. (1968) Components of the heart rate response in anticipation of RT and exercise tasks. Journal of Experimental Psychology, 78, 642-648.

Cohen, M.J., Johnson, H.J. & MacArthut, D.L. (1980) Interaction of a motor response, and reaction time and time estimation tasks, on heart rate and skin conductance. Psychophysiology, 17, 377-384.

Coles, M.G.H. (1972) Cardiac and respiratory activity during signal search. Journal of Experimental Psychology, 96, 2, 371-379.

Coles, M.G.H. (1974) Physiological activity and detection: The effects of attentional requirements and the prediction of performance. Biological Psychology, 2, 113-125.

Coles, M.G.H. & Duncan-Johnson, C.C. (1975) Cardiac activity and information processing: The effects of stimulus significance, and detection and response requirements. Journal of Experimental Psychology, 1, 4, 418-428.

Coles, M.G.H. & Duncan-Johnson, C.C. (1977) Attention and cardiac activity: Heart rate responses during a variable foreperiod, disjunctive reaction time task. Biological Psychology, 5, 151-158.

Cook, M.R. (1974) Psychophysiology of peripheral vascular changes. In P.A. Obrist, A.H. Black, J. Brener and L.V. Dicara (Eds.) Cardiovascular psychophysiology. Chicago: Aldine.

Craik, F.I.M. & Blankstein, K.R. (1975) Psychophysiology and human memory. In P.H. Venables & M.J. Christie (Eds.) Research in psychophysiology. Bristol: Wiley.

Dahl, H. & Spence, D.P. (1971) Mean heart rate predicted by task demand characteristics. Psychophysiology, 7, 3, 369-376.

Darrow, C.W. (1929) Differences in the physiological reactions to sensory and ideational stimuli. Psychological Bulletin, 26, 4, 185-201.

Darrow, C.W. (1929) Electrical and circulatory responses to brief sensory and ideational stimuli. Journal of Experimental Psychology, 12, 4, 267-300.

Darrow, C.W. (1936) The galvanic skin reflex (sweating) and blood pressure as preparatory and facilitative functions. Psychological Bulletin, 33, 73-94.

Darrow, C.W. (1937) Neural mechanisms controlling the palmar galvanic skin reflex and palmar sweating. Archives of Neurology and Psychiatry, 37, 641-663.

Darrow, C.W. & Solomon, A.P. (1934) Galvanic skin reflex and blood pressure reactions in psychotic states. Archives of Neurology and Psychiatry, 32, 273-299.

Darrow, C.W., Wilcott, R.C., Siegel, A. & Wilson, J. (1956) Central and peripheral indications of conditioning, adaptation, anticipation and extinction. Journal of Nervous and Mental Disease, 124, 1.

Dashiell, J. (1940) A neglected fourth dimension to psychological research. Psychological Review, 47, 289-305.

Davis, R.C. (1946) The psychophysiology of set. In P.L. Harriman (Ed.) Twentieth Century Psychology. New York: The Philosophical Library.

Davis, R.C. (1957) Response patterns. Transactions of the New York Academy of Sciences, 19, 731-739.

Davis, R.C., Buchwald, A.M. & Frankman, R.W. (1955) Autonomic and muscular responses, and their relation to the simple stimuli. Psychological Monographs, 69, 20, 1-71.

De Swart, J.H. & Das-Smaal, E.A. (1976) Relationship between SCR, heart rate and information processing. Biological Psychology, 4, 41-49.

Deane, G.E. (1961) Human heart responses during esperimentally induced anxiety. Journal of Experimental Psychology, 61, 489-493.

Deane, G.E. (1969) Cardiac activity during experimentally induced anxiety. Psychophysiology, 6, 1, 17-30.

Delius, J.D. (1979) Irrelevant behaviour, information processing and arousal homeostatis. Psychologische Forsching, 33, 165-188.

Dengerink, H.A. & Taylor, S.D. (1971) Multiple responses with differential properties in delayed galvanic skin response conditioning: A review. Psychophysiology, 8, 3, 348-360.

Donchin, E (1969) Discriminant analysis in average evoked response studies: The study of single trial data. Electroencephalography & Clinical Neurophysiology, 27, 311-314.

Donchin, E., Kubovy, M., Kutas, M., Johnson, R., & Herning, R.I. (1973) Graded changes in evoked response (p300) amplitude as a function of cognitive activity. Perception & Psychophysics, 14, 319-324.

Dronsejko, K. (1972) Effects of CS duration and instructional set on cardiac anticipatory responses to stress in field dependent and independent subjects. Psychophysiology, 9, 1, 1-13.

Duffy, E. (1951) The concept of energy mobilization. Psychological Review, 58, 30-40.

Duffy, E. (1957) The psychological significance of the concept of "arousal" or "activation". Psychological Review, 64, 5, 265-275.

Duffy, E. (1962) Activation and behavior. New York: Wiley.

Duffy, E. (1972) Activation. In N.S. Greenfield & R.A. Sternbach (Eds.) Handbook of Psychophysiology. New York: Holt, Rinehart & Winston, Inc.

Duncan-Johnson, C.C. & Coles, M.G.H. (1974) Heart rate and disjunctive reaction time: The effects of discrimination requirements. Journal of Experimental Psychology, 103, 6, 1160-1168.

Easterbrook, J.A. (1959) The effect of emotion on cue utilization and the organization of behavior. Psychological Review, 66, 183-201.

Edelberg, R. (1967) Electrical properties of the skin. In C. Brown (Ed.) Methods in psychophysiology. Baltimore: Williams & Wilkins.

Edelberg, R. (1972) The electrodermal system. In M.S. Greenfield and R.A. Sternbach (Eds.) Handbook of psychophysiology. New York: Holt, Rinehart & Winston, Inc.

Edelberg, R. (1973) Mechanisms of electrodermal adaptations for locomotions, manipulations, or defense. In E. Stellar and J.M. Sprague (Eds.) Progress in physiological psychology. Vol. 5. New York: Academic Press.

Edfeldt, A.W. (1960) Silent speech and silent reading. University of Chicago: Chicago Press.

Edwards, D.C. & Alsip, J.E. (1969) Intake-rejection, verbalization, and affect: Effects on heart rate and skin conductance. Psychophysiology, 6, 6-12.

Elliot, R. (1966) Effects of uncertainty about the nature and advent of a noxious stimulus (shock) upon heart rate. Journal of Personality and Social Psychology, 3, 353-356.

Elliott, R. (1969) Tonic heart rate: Experiments on the effects of collative variables lead to a hypothesis about its motivational significance. Journal of Personality and Social Psychology, 12, 3, 211-228.

Elliott, R. (1974) Further comment on the Lacey hypothesis. Journal of Personality and Social Psychology, 30, 1, 19-23.

Engel, B.T. (1972) Response specifity. In N. Greenfield and R. Sternbach (Eds.) Handbook of psychophysiology. London: Holt, Rinehart & Winston, Inc.

Engel, B.T. & Chism, R.A. (1967) Effect of increases and decreases in breathing rate on heart rate and finger pulse volume. Psychophysiology, 4, 1, 83-89.

Epstein, S. (1973) Expectancy and magnitude of reaction to a noxious UCS. Psychophysiology, 10, 1, 100-107.

Epstein, S., Boudreau, L. & Kling, S. (1975) Magnitude of the heart rate and electrodermal response as a function of stimulus input, motor output, and their interaction. Psychophysiology, 12, 1, 15-24.

Epstein, S. & Clark, S. (1970) Heart rate and skin conductance during experimentally induced anxiety. Effects of anticipated intensity of noxious stimulation and experience. Journal of Experimental Psychology, 84, 105-112.

Epstein, S., Rosenthal, S. & Szpiler, J. (1978) The influence of attention upon anticipatory arousal, habituation, and recovery to a noxious stimulus. Journal of Research in Personality, 12, 30-40.

Eysenck, H.J. (1978) Expectation as causal elements in behavioural change. Advances in Behaviour Research and Therapy, 1, 171-175.

Fowles, D.C. (1980) The three arousal model: Implications of Gray's two-factor learning theory for heart rate, electrodermal activity, and psychopathy. Psychophysiology, 17, 87-104.

Freeman, G.L. (1931) The spread of neuromuscular activity during mental work. Journal of General Psychology, 5, 479-494.

Freeman, G.L. (1939) The problem of set. American Journal of Psychology, 52, 16-30.

Freeman, G.L. (1948) The energetics of human behavior. Ithaca: Cornell University Press.

Friedman, D., Tursky, B. & Erlenmeyer-Kimling, L. (1980) Evoked cardiac waveform components during aversion and detection procedures. Physiological Psychology, 8, 4, 497-502.

Furedy, J.J. (1970) Test of the preparatory adaptive response interpretation of aversive classical autonomic conditioning. Journal of Experimental Psychology, 84, 2, 301-307.

Furedy, J.J. (1975) An integrative progress report on informational control in humans: Some laboratory findings and methodological claims. Australian Journal of Psychology, 27, 61-83.

Furedy, J.J. & Klajner F. (1974) On evaluating autonomic and verbal indices of negative preception. Psychophysiology, 11, 121-124.

Gaillard, A.W.K. (1977) The late CNV wave: Preparation versus expectancy.

Psychophysiology, 14, 563-568.

Gaillard, A.W.K. & Perdok, J. (1979) Slow cortical and heart rate correlates of discrimination performance. Acta Psychologica, 43, 185-198.

Gaines, L.S., Smith, B.D. & Skolnick, B.E., (1977) Psychological differentiation, event uncertainty, and heart rate. Journal of Human Stress, 3, 11-25.

Gal, R. & Lazarus, R.S. (1975) The role of activity in anticipating and confronting stressful situations. Journal of Human Stress, 1, 4-20.

Games, P.A., (1975) Computer programs for robust analyses in multifactor analysis of variance designs. Educational and Psychological Measurement, 35, 147-152.

Garrity, L. (1977) Electromyography: A review of the current status of subvocal speech research. Memory & Cognition, 5, 615-622.

Geer, J.H., Davison, G.C. & Gatchell, R.I. (1970) Reduction of stress in humans through nonveridical perceived control of aversive stimulation. Journal of Personality & Social Psychology, 16, 731-738.

Germana, J. (1969) Central efferent processes and autonomic behavioral integration. Psychophysiology, 6, 1, 70-78.

Gibson, J.J. (1941) A critical review of the concept of set in contemporary experimental psychology. Psychological Bulletin, 38, 781-817.

Gliner, J.A., Bedi, J.F. & Horvath, S.M. (1979) Somatic and non-somatic influences on the heart: Hemodynamic changes. Psychophysiology, 16, 358-362.

Goldstein, I.B. (1972) Electromyography: A measure of skeletal muscle response. In N.S. Greenfield & R.A. Sternbach (Eds.) Handbook of psychophysiology. New York: Holt, Rinehart & Winston, Inc.

Granit, R. (1977) The purposive brain. Cambridge: Mit.

Granit, R. (1980) Reflections on motricity. Perspectives in Biology and Medicine, 23,171-178.

Gray, J.A. (1977) Drug effects on fear and frustration: Possible limbic site of action of minor tranquilizers. In L.L. Iversen, S.D. Iversen & S.H. Snyder (Eds.) Handbook of psychopharmacology. Vol. 8. Drugs neurotransmitters and behaviour. New York: Plenum.

Green, J. (1980) A review of the Lacey's physiological hypothesis of heart rate change. Biological Psychology, 11, 63-80.

Grings, W.W. (1960) Preparatory set variables in the classical conditioning of autonomic variables. Psychological Review, 67, 242-252.

Grings, W.W. (1969) Anticipatory and preparatory electrodermal behaviour in paired stimulus situations. Psychophysiology, 5, 597-611.

Grings, W.W. (1973) Cognitive factors in electrodermal conditoning. Psychological Bulletin, 79, 3, 200-210.

Grings, W.W. (1979) Interrelationships among components of orienting behavior. In H.D. Kimmel, E.H. van Olst & J.F. Orlebeke (Eds.) The orienting reflex in humans. New Jersey: Lawrence Erlbaum.

Grings, W.W. & Carlin, S. (1962) Set, suggestion, and conditioning. Journal of Experimental Psychology, 63, 5, 417-422.

Grings, W.W. & Dawson, M.E. (1973) Complex variables in conditioning. In W.F. Prokasy and P. Raskin (Eds.) Electrodermal activity in psychological research. New York: Academic Press.

Grings, W.W. & Lockhart, R.A. (1965) Problems of magnitude measurement with multiple GSR. Psychological Reports, 17, 979-982.

Grings, W.W. & Sukoneck, H. (1971) Prediction probability as a determiner of anticipatory and preparatory behavior. Journal of Experimental Psychology, 91, 310-317.

Grings, W.W., Vucelic, I. & Peeke, S.C. (1980) The effects of expectancy upon electrodermal responses to signaled stimuli. Psychophysiology, 17, 390-395.

Grossberg, S. (1980) How does a brain build a cognitive code? Psychological Review, 87, 1-42.

Hamilton, R., Hockey, B. & Rejman, M. (1977) The place of the concept of activation in human information processing theory: An integrative approach. In S. Dornic (Ed.) Attention and performance VI. New York: LEA.

Harding, G.B., Stevens, E. & Marston, P. (1973) Rate of information processing and skin resistance. Journal of Experimental Psychology, 99, 306.

Hare, R.D. (1972) Response requirements and directional fractionation of autonomic responses. Psychophysiology, 9, 4, 419-427.

Hare, R.D. (1982) Psychopathy and physiological activity during anticipation of an aversive stimulus in a distraction paradigm. Psychophysiology, 19, 3, 266-271.

Hasset, J. (1978) A primer of psychophysiology. San Francisco: Freeman & Co.

Hathaway, K.M. & McCanne, T.R. (1979) Autonomic and somatic responses associated with performance of the embedded figures test. Psychophysiology, 16, 8-14.

Hebb, D.O. (1949) The organization of behaviour. New York: Wiley.

Hebb, D.O. (1955) Drives and the CNS (conceptual nervous system). Psychological Review, 62, 243-254.

Hess, E.H. & Polt, J.M. (1964) Pupil size in relation to mental activity during simple problem-solving. Science, 143, 1190-1192.

Higgins, C. (1971) Set and uncertainty as factors influencing anticipatory cardiovascular responding in humans. Journal of Comparative and Physiological Psychology, 74, 2, 272-283.

Hockey, R. (1979) Stress and the cognitive components of skilled performance. In V. Hamilton & D.M. Warburton (Eds.) Human stress and cognition. New York: Wiley.

Hokanson, J.E. (1969) The psychological bases of motivation. New York: Wiley.

Hokanson, J.E., Degood, D.E., Forrest, M.S. & Brittain, B.M. (1971) Availability of avoidance behaviours in modulating vascular-stress responses. Journal of Personality & Social Psychology, 19, 60-68.

Holloway, F.A. & Parsons, O.A. (1972) Physiological concomitants of reaction time performance. Psychophysiology, 9, 189-198.

Hull, C.L. (1943) Principles of behavior. New York: Appleton-Century-Crofts.

Ikonen, S. & Lyytinen, H. (1972) Manifestations of attention and motor activity in heart rate and skin conductance changes. Reports from the Department of Psychology, University of Jyväskylä, 122. (In Finnish).

Jacobson, E. (1973) Electrophysiology of mental activities and introduction to the psychological process of thinking. In F.J. McGuigan and R.A. Schoonover (Eds.) The psychophysiology of thinking. New York: Academic Press.

James, W. (1890) The principles of psychology. New York: Holt, Rinehart & Winston, Inc.

Jasper, H. (1958) Reticular-cortical systems and theories of the integrative action of the brain. In H.F. Harlow & C.N. Woolsey (Eds.) Biological and biochemical bases of behavior. Madison: University of Wisconsin Press.

Jennings, J.R. (1982) Beat-by-beat vascular responses during anticipatory heart rate deceleration. Physiological Psychology, 10, 422-434.

Jennings, J.R., Averill, J., Opton, E. & Lazarus, R. (1971) Some parameters of HR change: Perceptual versus motor task requirements, noxiousness, and uncertainty. Psychophysiology, 7, 2, 194-212.

Jennings, J.R. & Hall, S.W., JR. (1980) Recall, recognition, and rate: Memory and the heart. Psychophysiology, 17, 37-46.

Johnson, D.A. (1971) Pupillary responses during a short-term memory task: Cognitive processing, arousal, or both? Journal of Experimental Psychology, 90, 2, 311-318.

Johnson, H.J. & Campos, J.J. (1967) The effect of cognitive tasks and verbalization instructions on heart rate and skin conductance. Psychophysiology, 4, 143-150.

Johnson, H.J. & May, J.R. (1969) Phasic heart rate changes in reaction time and time estimation. Psychophysiology, 6, 3, 351-357.

Jones, G.E. & Johnson, H.J. (1978) Physiological responding during self-generated imagery of contextually complete stimuli. Psychophysiology, 15, 439-446.

Jones, G.E. & Johnson, H.J. (1980) Heart rate and somatic concomitants of mental imagery. Psychophysiology, 17, 339-347.

Kahneman, D., Tursky, B., Shapiro, D. & Crider, A. (1969) Pupillary, heart rate, and skin resistance changes during a mental task. Journal of Experimental Psychology, 79, 1, 164-167.

Kaiser, D.N. & Sandman, C.A. (1975) Physiological patterns accompanying complex problem solving during warning and nonwarning conditions. Journal of Comparative and Physiological Psychology, 89, 4, 357-363.

Kaplan, B.E., Corby, J. & Leiderman, P. (1971) Attention and verbalization: Differential responsivity of cardiovascular and electrodermal systems. Journal of Psychosomatic Research, 15, 323.

Kerr, B. (1973) Processing demands during mental operations. Memory & Cognition, 1, 4, 401-412.

Kilpatrick, D.G. (1972) Differential responsiveness of two electrodermal indices to psychological stress and performance of a complex cognitive task. Psychophysiology, 9, 2, 218-226.

Kimmel, H.D. (1966) Inhibition of the unconditioned response in classical conditioning. Psychological Review, 73, 232-240.

Kimmel, H.D. & Pennypacker, H.S. (1962) Conditioned diminution of the unconditioned response as a function of the number of reinforcements. Journal of Experimental Psychology, 64, 20-23.

Klorman, R. & Bentsen, E. (1975) Effects of warning-signal duration on the early and late components of the contingent negative variation. Biological Psychology, 3, 263-275.

Klorman, R., Weissberg, R.P. & Wiesenfeld, A.R. (1977) Individual differences in fear and autonomic reactions to affective stimulation. Psychophysiology, 14, 1, 45-51.

Koizumi, K. & Brooks, C. (1972) The integration of autonomic system reactions: A discussion of autonomic reflexes, their control and their association with somatic reactions. In Reviews of physiology, biochemistry and experimental pharmacology, 67. Berlin: Springer.

Kornhuber, H.H. & Deecke, L. (1965) Hirnpotentialanderungen bei Willkurbewegungen und passiven Bewegungen des Menschen. Bereitschaftspotential und reafferente potentiale. Pflugers Archiv, 284, 1-17.

Kvasov, D.G. & Korovina, M.V. (1965) The reflex organization of perception and the propriomuscular apparatus of the analyzers (of the sense organs). In L.G. Voronin, A.R. Leontiev, A.R. Luria, E.N Sokolov & O.S. Vinogradova (Eds.) Orienting reflex and exploratory behavior. Washington: American Institute of Biological Sciences.

Lacey, B.C. & Lacey, J.I. (1980) Cognitive modulation of time-dependent primary bradycardia. Psychophysiology, 17, 209-221.

Lacey, J.I. (1967) Somatic response patterning and stress: some revisions of activation theory. In M. Appley and R. Trumbull (Eds.) Psychological stress: Issues in research. New York: Appleton-Century-Crofts.

Lacey, J.I. (1972) Some cardiovascular correlates of sensorimotor behavior: Examples of visceral afferent feedback? In C.H. Hokman (Ed.) Limbic system mechanisms and autonomic function. Thomas: Springfield.

Lacey, J.I., Bateman, D.E. & Vanlehn, R. (1953) Autonomic response specificity: An experimental study. Psychosomatic Medicine, 15, 8-21.

Lacey, J.I., Kagan, J., Lacey, B.C. & Moss, H.A. (1963) The visceral level: Situational determinants and behavioral correlates of autonomic response patterns. In P.H. Knapp (Ed.) Expressions in the emotions in man. New York: International Universities Press.

Lacey, J.I. & Lacey, B.C. (1958) Verification and extension of the principle of autonomic response-stereotypy. American Journal of Psychology, 71, 50-73.

Lacey, J.I. & Lacey, B.C. (1970) Some autonomic latency correlates of rule induction. Psychonomic science, central nervous system interrelationships. In P. Black (Ed.) Physiological correlates of emotion. New York: Academic Press.

Lacey, J.I. & Lacey, B.C. (1980) The specific role of heart rate in sensorimotor integration. In R.F. Thompson, L.H. Hicks & V.B. Shvyrkov (Eds.) Neural mechanisms of goal directed behavior and learning. New York: Academic Press.

Lachin, J.M., & Schachter, J. (1974) On stepwise discriminant analyses applied to physiologic data. Psychophysiology, 11, 703-709.

Lang, P.J. (1979) A bio-informational theory of emotional imagery. Psychophysiology, 16, 495-512.

Lang, P.J., Gatchel, R.J. & Simons R.F. (1975) Electro-cortical and cardiac rate correlates of psychophysical judgment. Psychophysiology, 12, 6, 649-656.

Lang, P.J., Kozak, M.J., Miller, G.A., Levin, D.N. & McLEAn, A., JR. (1980) Emotional imagery: Conceptual structure and pattern of somato- visceral response. Psychophysiology, 17, 179-192.

Lang, P.J., Öhman, A. & Simons, R.F. (1978) The psychophysiology of anticipation. In J. Requin (Ed.) Attention and performance VII. Hillsdale: Lawrence Erlbaum.

Lanzetta, J.T. & Driscoll, J.M. (1966) Preference for information about an uncertain but unavoidable outcome. Journal of Personality and Social Psychology, 3, 96-102.

Locke, J.L. & Fehr, J.S. (1970) Subvocal rehearsal as a form of speech. Journal of Verbal Learning and Verbal Behavior, 9, 495-498.

Lockhart, R.A. (1973) Cognitive processes and the multiple response phenomenon. Psychophysiology, 10, 1, 112-118.

Lomov, B.F. & Surkov, E.N. (1980) On anticipation levels in activity structure. Studia Psychologica, 22, 1, 29-40. Luria, A.R. (1973) The working brain. London: Penguin.

Lykken, D.T. (1959) Preliminary observation on the preception phenomenon. Psychological Measurements Newsletter, 5, 2-4.

Lykken, D.T. (1962) Preception in the rat: Autonomic response to shock as a function of length of warning signal. Science, 137, 665-666.

Lykken, D.T., Macindoe, I. & Tellegen, A. (1972) Preception: autonomic response to shock as a function of predictability in time and locus. Psychophysiology, 9, 318-333.

Lykken, D.T. & Tellegen, A. (1974) On the validity of the preception hypothesis. Psychophysiology, 11, 125-132.

Lyytinen, H. (1970) Autonomic conditioning and personality. Department of Psychology, University of Jyväskylä. An unpublished master´s thesis. (In Finnish).

Lyytinen, H. (1974) Learning as manifested in the phasic psychophysiological responses. Department of Psychology, University of Jyväskylä. An unpublished licenciate´s thesis. (In Finnish).

Lyytinen, H. (1975a) Autonomic conditioning. An example of a specifically human form of autonomic response modification. Reports from the Department of Psychology, University of Jyväskylä, 167.

Lyytinen, H. (1975b) Semantic autonomic conditioning. An example of a specifically human form of autonomic response modification. Reports from the Department of Psychology, University of Jyväskylä, 168.

Lyytinen, H. (1975c) Cognition and phasic arousal. Acta Psychologica Fennica IV. Helsinki: Finnish Psychological Society.

Lyytinen, H. (1978) Learning disability and phasic arousal. Reports from the Department of Psychology, University of Jyväskylä, 208.

Lyytinen, H. (1981) Effects of arousal manipulations on autonomic and cortical slow potential responses in forewarned RT-tasks. Biological Psychology, 11, 3, 289-290.

Lyytinen, H. (1982a) Psychophysiology of anticipation. In Soviet-Finnish symposium on psychophysiology. Publications of the Finnish-Soviet Committee on Scientific-Technological Cooperation, No 15, 103-148.

Lyytinen, H. (1982b) Preactivity as an object of psychophysiological study. Acta Psychologica Fennica, IX. Helsinki: Suomen Psykologinen Seura.

Lyytinen, H. (1982c) Preactivity phenomena in psychological research: Ideas and labels. Department of Psychology, University of Jyväskylä. An unpublished manuscript.

Lyytinen, H. (1983a) A component analysis of multi-channel arousal patterns. In R. Sinz & M.R. Rosenzweig (Eds.) Psychophysiology 1981: Memory, motivation and event- related potentials in mental operations. Jena: Veb/Gustav Fischer Verlag. Amsterdam: Elsevier Biomedical Press.

Lyytinen, H. (1983b) Arousal, anticipation and attention. A psychophysiological perspective. (Submitted for publication).

Lyytinen, H. (1984) Anticipation as an object of psychophysiological study. To be published in Reports from the Department of Psychology, University of Jyväskylä.

Lyytinen, H., Ahonen, T., Partanen, T. & Pietiläinen R. (1977) Pattern of phasic arousal related to variation in cognitive effort with special reference to speech organ EMG and age effects. In abstracts of the fifth Scandinavian meeting on psychology and behavior.

Lyytinen, H. & Koskinen, R. (1976) A program package for computer-mediated quantification of autonomic responses: description of the programs and user´s manual. Department of Psychology, University of Jyväskylä. An unpublished duplicate. (In Finnish).

Mandler, G. (1975) Mind and emotion. New York: Wiley.

McArthur, D.L., Cohen, M.J. & Johnson, H.J. (1980) Interaction of a motor response, and reaction time estimation tasks, on heart rate and skin conductance. Psychophysiology, 17, 377-384.

McCanne, T.R. & Hathaway, K.M. (1979) Autonomic and somatic responses associated with performance of the embedded figures test. Psychophysiology, 16, 8-14.

McGuigan, F.J. (1978) Cognitive psychophysiology - principles of covert behaviour. Englewood Cliffs, N.J.:Prentice-Hall.

McGuinness, D. & Pribram, K. (1980) The neuropsychology of attention: Emotional and motivational controls. In M.C. Wittrock (Ed.) The brain and psychology. New York: Academic Press.

Mefferd, R.B. & Wieland, B. (1966) Comparison of responses to anticipated stress. Psychosomatic Medicine, 28, 6, 795-807.

Mitchell, J.H., Sproule, B.J. & Chapman, C.B. (1958) The physiological meaning of the maximal oxygen intake test. Journal of Clinical Investigations, 37.

Montgomery, C.K. (1977) Effects of performance evaluation and anxiety on cardiac response in anticipation of difficult problem solving. Psychophysiology, 14, 3, 251-237.

Moruzzi, G. & Magoun, E.W. (1949) Brain-stem reticular formation and activation of the EEG. EEG Clinical Neurophysiology I, 455-473.

Mowrer, O. (1938) Preparatory set (expectancy) - a determinant in motivation and learning. Psychological Review, 45, 62-91.

Neisser, U. (1967) Cognitive psychology. New York: Appleton-Century-Crofts. Neisser, U. (1976) Cognition and reality. San Francisco: Freeman.

Neisser, U. (1978) Anticipations, images and introspection. Cognition. 6, 169-174.

Niemelä, P. (1969a) Electrodermal responses as a function of quantified threat. Scandinavian Journal of Psychology, 10, 49-56.

Niemelä, P. (1969b) Heart rate responses during anticipation of an electric shock of variable probability. Scandinavian Journal of Psychology, 10, 232-242.

Niemelä, P. (1973) Coping processes in the anticipation of stress. Reports from the psychological laboratories. The University of Stockholm. Supplement 20.

Nunnally, J.C., Knott, P.D., Puchnowski, A. & Parker, R. (1967) Pupillary response as a general measure of activation. Perceptual Psychophysics, 2, 149-155.

Näätänen, R. (1970) Evoked potential, EEG and slow potential correlates of selective attention. In A.F. Sanders (Ed.) Attention and performance III. Acta Psychologica, 33, 178-192.

Näätänen, R. (1973) The inverted-U relationship between activation and performance IV. New York: Academic Press.

Näätänen, R. (1975) Selective attention and evoked potentials in humans - a critical review. Biological Psychology, 2, 237-307.

Näätänen, R. (1977) Significance of slow potential shifts in anticipation of and during task performance. In D.A. Otto (Ed.) Multidisciplinary perspectives in event-related brain potential research. Health effects research laboratory, Research Triangle Park, North Carolina, USA.

Näätänen, R. & Merisalo, A. (1977) Expectancy and preparation in simple reaction time. In S. Dornic (Ed.) Attention and performance II. Hillsdale: Lawrence Erlbaum.

Näätänen, R. & Summala, H. (1976) Road-user behavior and traffic accidents. Amsterdam: North-Holland Publishing Company.

Obrist, P.A. (1963) Cardiovascular differentiation of sensory stimuli. Psychosomatic Medicine, 25, 5, 450-459.

Obrist, P.A. (1976) The cardiovascular-behavioral interaction - as it appears today. Psychophysiology, 13, 2, 95-107.

Obrist, P.A., Howard, J.L., Lawler, J.E., Galosy, R.A., Meyers, K.A. & Gaebelein, C. (1974) The cardiac-somatic interaction. In P.A. Obrist, A.H. Black, J. Brewer & L.V. Dicara (Eds.) Cardivascular psychophysiology. Chicago: Aldine.

Obrist, P.A., Webb, R.A. & Sutterer, J.R. (1969) Heart rate and somatic changes during aversive conditioning and a simple reaction time task. Psychophysiology, 5, 696-723.

Obrist, P.A., Webb, R.A., Sutterer, J.R. & Howard, J.L. (1970) Cardiac deceleration and reaction time: An evaluation of two hypotheses. Psychophysiology, 6, 693-706.

Obrist, P.A., Webb, R.A., Sutterer, J.R. & Howard, J.L., (1970) The cardiac-somatic relationship: Some reformulations. Psychophysiology, 6, 5, 569-587.

Öhman, A. (1971) Interaction between instruction-induced expectancy and strenght of unconditioned stimulus in GSR conditioning. Journal of Experimental Psychology, 88, 318-333.

Öhman, A. (1972) Factor analytically derived components of, orienting, defensive and conditioned behavior in electrodermal conditioning.

Psychophysiology, 9, 199-209.

Öhman, A. (1974) The relationship between electrodermal and digital vasomotor responses in aversive classical conditioning. Biological Psychology, 2, 1, 17-31.

Öhman, A. (1979) Orienting response, attention, and learning: An information-processing perspective. In H.D. Kimmel, E.H. van Olst & J.F. Orlebeke (Eds.) The orienting reflex in humans. New Jersey: Lawrence Erlbaum.

Öhman, A., Björkstrand, P-E. & Ellström, P-E. (1973) Effect of explicit trial-by-trial informatio about shock probability in long interstimulus interval GSR conditioning. Journal of Experimental Psychology, 98, 1, 145-151.

Öhman, A. & Hugdahl, K. (1979) Instructional control of autonomic respondents: Fear relevance as a critical factor. In N. Birbaumer & H.D. Kimmel (Eds.) Biofeedback and self-regulation. New York: LEA.

O'Connor, K. (1981) The intentional paradigm and cognitive psychophysiology. Psychophysiology, 18, 2, 121-128.

Orlebeke, J.F. & van Doornen, L.J.P. (1977) Preception (UCR diminution) in normal and neurotic subjects. Biological Psychology, 5, 15-22.

Peeke, S.C. & Grings, W.W. (1968) Magnitude of CR as a function of variability in the CS-UCS relationship. Journal of Experimental Psychology, 77, 64-69.

Perkins, C.C. (1968) An analysis of the concept of reinforcement. Psychological Review, 75, 155-172.

Petry, H.M. & Desiderato, O. (1978) Changes in heart rate, muscle activity, and anxiety level following shock threat. Psychophysiology, 15, 5, 398-402.

Polt, J.M. (1970) Effect of threat of shock on pupillary response in a problem-solving situation. Perceptual and Motor Skills, 31, 587-593.

Porges, S.W. & Raskin, D.C. (1969) Respiratory and heart rate components of attention. Journal of Experimental Psychology, 81, 497-503.

Pribram, K.H. & McGuinness, D. (1975) Arousal, activation and effort in the control of attention. Psychological Review, 82, 2, 116-149.

Prigatano, G.P. & Johnson, H.J. (1974) Autonomic nervous system changes associated with a spider phobic reaction. Journal of Abnormal Psychology, 83, 169-177.

Pugh, L.A., Oldroyd, C.A., Ray T.S. & and Clark, M.L. (1966) Muscular effort and electrodermal responses. Journal of Experimental Psychology 71, 241-248.

Punch, J.C. & King, M.G. (1976) Effects of signaled and unsignaled stressor on ECG T-wave amplitude. Physiology & Behavior, 17, 227-229.

Ray, R.L., Piroch, J.F. & Kimmel, H.D. (1977) The effect of task and stimulus variability on habituation of electrodermal and vasomotor reactions. Physiological Psychology, 5, 189-196.

Requin, J., Bonnet, M. & Semjen, A. (1977) Is there a specificity in the supraspinal control of motor structures during preparation? In S. Dornic (Ed.) Attention and performance VI. New Jersey: Lawrence Erlbaum.

Ritter, W., Vaughan, H.G. & Costa, L.D. (1968) Orienting and habituation to auditory stimuli: A study of short-term changes in average evoked responses. Electroencephalography and Clinical Neurophysiology, 25, 550-556.

Roessler, R., Engel, B.T. (1977) The current status of the concepts of physiological response specificity and activation. In Z.J. Lipowski, D.R. Lipsett & P.C. Whybrow (Eds.) Psychosomatic medicine. Current trends and clinical applications. New York: Oxford University Press.

Roth, W.T. (1973) Auditory evoked responses to unpredictable stimuli. Psychophysiology, 10, 125-138.

Routtenberg, A. (1968) The two-arousal hypothesis: Reticular formation and limbic system. Psychological Review, 75, 51-80.

Ruttkay-Nedecky, I. (1980) Mechanisms of the influence of psychic factors on cardiac activity. Activitas Nervorum Supplement, 22, 130-137.

Sampson, J.R. (1969) Further study of encoding and arousal factors in free recall of verbal and visual material. Psychonomic Science, 16, 221-222.

Sanders, A.F. (1966) Expectancy: Application and measurement. Acta Psychologica, 25, 293-313.

Schafer, E.W., Amochaev, A. & Russell, M.J. (1981) Knowledge of stimulus timing attenuates human evoked cortical potentials. Electroencephalography and Clinical Neurophysiology, 52, 9-17.

Schell, A. & Grings, W. (1971) Avoidance conditioning of the GSR: nature of the response. Psychophysiology, 7, 3, 402-407.

Schell, A.M. & Catania, J. (1975) The relationship between cardiac activity and sensory acuity. Psychophysiology, 12, 147-151.

Scher, H. & Furedy, J.J. (1982) Changes in heart rate and T-wave amplitude during anticipation and performance of a backward digit span task. Psychophysiology, 19, 3, 347.

Schmidt, C. von, Dettmar, P., Petzold, P., Richter, P. & Schmidt, C.F. (1980) Die Verwendung tonischer und phasischer Parameter der Herzfrequenz zur psychophysiologischen Aufwandskennzeichnung kognitiver Leistungen. In W. Hacker & H. Raum (Hrsg.) Tätigkeitsoptimisierung. Berlin: Veb/Deutscher Verlag der Wissenschaften.

Schneiderman, N. (1974) The relationship between learned and unlearned cardiovascular response. In P.A. Obrist, A.H. Black, J. Brener and L.V. Dicara (Eds.) Cardiovascular psychophysiology. Chicago: Aldine.

Schwartz, G.E., Fair, P.L., Salt, P., Mandel, M.R. & Klerman, G.L. (1976) Facial muscle pattering to affective imagery in depressed and non-depressed subjects. Science, 192, 489-491.

Schwartz, G.E. & Higgins, J.D. (1971) Cardiac activity preparatory to overt and covert behavior. Science, 13, 1144-1146.

Schwartz, G.E. & Higgins, J.D. (1977) Response imperativeness and the cardiac waveform during the preparation of a motor and 'mental' reaction response. Psychophysiology, 8, 243.

Schwartz, G.E., Weinberger, D.A. & Singer, J.A. (1981) Cardiovascular differentiation of happiness, sadness, anger, and fear following imagery and exercise. Psychosomatic Medicine, Vol. 43, 343-364.

Sersen, E.A., Clausen, J. & Lidsky, A. (1978) Autonomic specificity and stereotypy revisited. Psychophysiology, 15, 1, 60-67.

Sharples, F. & Jasper H.H. (1956) Habituation of the arousal reaction. Brain, 79.

Shell, A.M. & Catania, J. (1975) The relationship between cardiac activity and sensory acuity. Psychophysiology, 12, 147-151.

Sherrington, C.S. (1952) Man on his nature. London: Cambridge University Press.

Siegel, J.M. (1979) Behavioral functions of the reticular formation. Brain Research Reviews, 1, 69-105.

Shiomi, K. (1974) The roles of anticipation and defense mechanism in experimentally induced anxiety. Psychologia, 17, 150-158.

Simons, R.F., Öhman, A. & Lang, P.J. (1979) Anticipation and response set: Cortical, cardiac, and electrodermal correlates. Psychophysiology, 16, 3, 223-233. Sokolov, A.N. (1972) Inner speech and thought. New York: Plenum.

Sokolov, E.N. (1963) Perception and the conditioned reflex. New York: Pergamon Press.

Somsen, R.J.M., van der Molen, M.W. & Orlebeke, J.F. (1983) Phasic heart rate changes in reaction time, shock avoidance and unavoidable shock tasks: Are hypothetical generalizations about different s1-s2 tasks justified? Psychophysiology, 20, 1, 88-94.

Sperry, R.W. (1952) Neurology and the mind-brain problem. American Scientist, 40, 291-312.

Stamps, L.E., Folse II, E.J., Fehr, L.A., Eason, B.L., Rizzo, A.A. & Smith, T.L. (1981) Anticipatory cardiac deceleration prior to total body movement in grade school children. Biological Psychology, 12, 305-312.

Stanners, R.F., Coulter, M., Sweet, A.W. & Murphy, P. (1979) The pupillary response as an indicator of arousal and cognition. Motivation and Emotion, 3,4, 219-339.

Stern, J.A. (1964) Toward a definition of psychophysiology. Psychophysiology, 1, 90-91.

Stern, J.A. (1972) Physiological response measures during classical conditioning. In N. Greenfield and R. Sternbach (Eds.) Handbook of psychophysiology, New York: Holt, Rinehart & Winston, Inc.

Sternbach, R.A. (1966) Principles of psychophysiology. New York: Academic Press.

Sutton, S., Braren, M., Zubin, J. & John, E.R. (1965) Evoked potential correlates of stimulus uncertainty. Science, 150, 1187-1188.

Takala, M. (1969) The problems of motivation in psychological theory. Proceedings of the Finnish Academy of Science and Letters. Helsinki: Sanomaprint.

Tarchanoff, J. (1976) Galvanic phenomena in the human skin during stimulation of the sensory organs and during various forms of mental activity. In S.W. Porges & M.G.H. Coles (Eds.) Psychophysiology. Stroudsburg: Dowden, Hutchinson & Ross Inc.

Tharp, V.K., Maltzman, I., Syndulko, K. & Ziskind, E. (1980) Autonomic activity during anticipation of an aversive tone in noninstitutionalized sociopaths. Psychophysiology, 17, 2, 123-128.

Thayer, R.E. (1970) Activation states as assessed by verbal reports and four psychophysiological variables. Psychophysiology, 7, 86-94.

Thayer, R.E. (1978) Toward a psychological theory of multidimensional activation (arousal). Motivation and Emotion, 2, 1, 1-34.

Tolman, E.C. (1932) Purposive behaviour in animals and men. New York: Appleton-Century-Crofts.

Treisman, M. & Howarth, C.I. (1959) Changes in threshold level produced by a signal preceding or following the threshold stimulus. Quarterly Journal of Experimental Psychology, 11, 129-142.

Tursky, B., Schwartz, G.E. & Crider, A. (1970) Differential patterns of heart rate and skin resistance during a digit-transformation task. Journal of Experimental Psychology, 83, 3, 451-457.

Tursky, B., Shapiro, D. & Crider, A. (1969) Pupillary, heart rate, and skin resistance changes during a mental task. Journal of Experimental Psychology, 79, 1, 164-167.

Uznadze, D.N. (1966) The Psychology of set. New York: Consultants Bureau.

Vanderwolf, C.H. & Robinson, T.E. (1981) Reticulo-cortical activity and behavior: A critique of the arousal theory and a new synthesis. The Behavioral and Brain Sciences, 4, 459-514.

Vinogradova, O. (1965) Spesific and nonspesific response systems in the formation of conditioned responses in man. In M. Cole & I. Maltzman (Eds.) A handbook of contemporary soviet Psychology. New York: Basic Books.

Waid, W.M. (1979) Perceptual preparewdness in man: Brief forewarning reduces electrodermal and psychophysical response to noxious stimulation. Psychophysiology, 16, 3, 214-221.

Wallin, B.G. (1981) Sympathetic nerve activity electodermal and cardiovascular reactions in man. Psychophysiology, 18, 4, 470-476.

Walter, G.F. & Porges, S.W. (1976) Heart rate and respiratory responses as a function of task difficulty: The use of discriminant analysis in the selection of psychologically sensitive physiological responses. Psychophysiology, 13, 6, 563-551.

Walter, W.G., Cooper, R., Aldridge, V.J., & Winter, A.L. (1964) Contingent negative variation: An electric sign of sensorimotor association and expectancy in the human brain. Nature, 203, 380-384.

Weiss, J.M. (1970) Somatic effects of predictable and unpredictable shock. Psychosomatic Medicine, 32, 397-408.

Weiss, J.M. (1971) Effects of coping behaviour in different warning signal conditions on stress pathology in rats. Journal of Comparative & Physiological Psychology, 77, 1-13.

Wenger, M.A. (1966) Studies of autonomic balance: A summary. Psychophysiology, 2, 173-186.

White, E. (1965) Autonomic responsivity as a function of level of subject involvement. Behavioral Science, 10, 39-50.

Williams, R.B., Bittker, T.E., Buchsbaum, M.S. & Wynne, L.L. (1975) Cardiovascular and neurophysiological correlates of sensory intake and rejection. I. Effects of cognitive tasks. Psychophysiology, 12, 4, 427-433.

Wilson, G.D. (1968) Reversal of differential GSR conditioning by instructions.

Journal of Experimental Psychology, 76, 491-493.

Woodworth, R.S. (1918) Dynamic psychology. New York: Columbia University Press.

Woodworth, R.S. (1921) Psychology: A study of mental life. New York: Holt, Rinehart & Winston, Inc.

Woodworth, R.S. (1937a) Psychology (Rev.ed.). New York: Holt, Rinehart & Winston, Inc.

Woodworth, R.S. (1937b) Situation-and-goal set. American Journal of Psychology, 50, 130-140.

Woodworth, R.S. (1938) Experimental psychology. New York: Holt, Rinehart & Winston, Inc.

Yaremko, R.M. & Butler, M.C. (1975) Imaginal experience and attenuation of the galvanic skin response to shock. Bulletin of the Psychonomic Society, 5, 4, 317-318.

Yaremko, R.M. & Werner, M. (1974) Cognitive conditioning: Imagined stimulus contiguity and the third interval conditional GSR. The Pavlovian Journal of Biological Science, 9, 4, 215-221.

Zeaman, D. & Smith, R.W. (1965) Review of some recent findings in human cardiac conditioning. In W.F. Prokasy (Ed.) Classical conditioning: A symposium. New York: Appleton-Century-Crofts.

APPENDIX I

Abbreviations of the physiological measures

SCR	Skin conductance
SCR1	Skin conductance, first interval
SCR2	Skin conductance, second interval
SCR3	Skin conductance, third interval
FPA	Finger pulse amplitude
FPA1	Pulse amplitude, first interval
FPA2	Pulse amplitude, second interval
FPA3	Pulse amplitude, third interval
HR	Heart rate
HRm1	Heart rate mean acceleration, first interval
HRm2	Heart rate mean acceleration, second interval
HRm3	Heart rate mean acceleration, third interval
HRp1	Heart rate peak acceleration, first interval
HRp2	Heart rate peak deceleration, second interval
HRp3	Heart rate peak acceleration, third interval
Rdis1	Respiration disturbance, first interval
Rdis2	Respiration disturbance, second interval
Rdis3	Respiration disturbance, third interval
Rdur1	Respiration cycle duration, first interval
Rdur2	Respiration cycle duration, second interval
Rdur3	Respiration cycle duration, third interval
BV	Blood volume
BVca	Blood volume constriction during pre-S2 intervals
BVcb	Blood volume constriction after S2 onset
BVda	Blood volume dilation during pre-S2 intervals
BVdb	Blood volume dilation after S2 onset
EMG	Electromyography
flEMG1	Flexor EMG, first interval
flEMG2	Flexor EMG, second interval
flEMG3	Flexor EMG, third interval
frEMGd1	Frontal EMG decrease, first interval
frEMGd2	Frontal EMG decrease, second interval
frEMGd3	Frontal EMG decrease, third interval
frEMGi1	Frontal EMG increase, first interval
frEMGi2	Frontal EMG increase, second interval
frEMGi3	Frontal EMG increase, third interval
orEMGd1	Orbicularis oris EMG decrease, first interval
orEMGd2	Orbicularis oris EMG decrease, second interval
orEMGd3	Orbicularis oris EMG decrease, third interval
orEMGi1	Orbicularis oris EMG increase, first interval
orEMGi2	Orbicularis oris EMG increase, second interval
orEMGi3	Orbicularis oris EMG increase, third interval

Abbreviations of the experimental conditions and groups

Ar	Arithmetic task condition
Me	Memory task condition
Mo	Motor (RT-) condition
Se	Sensory task condition
sS	shock-Stimulus condition
tS	tone-Stimulus condition
NI	Noninformed group
PI	Partially Informed group
FI	Fully Informed group
SE	Sensitization group

Abbreviations of rating- and performance variables

RT	reaction time
PT	performance time
UN	unpleasantness
DI	difficulty
MP	memory performance
AP	arithmetic performance

APPENDIX 2

Table 1. Skin conductance: ANOVA summary and significant mean differences

Table 2. Pulse amplitude: ANOVA summary and significant mean differences

Table 3. Heart rate: ANOVA summary and significant mean differences

Table 4. Respiratory disturbances: ANOVA summary and significant mean differences

Table 5. Duration of the respiratory cycle: ANOVA summary and significant mean differences

Table 6. Blood volume: ANOVA summary and significant mean differences

Table 7. EMG increase in the forearm flexors: ANOVA summary and significant mean differences

Table 8. EMG increase in the frontalis: ANOVA summary and significant mean differences

Table 9. EMG decrease in the frontalis: ANOVA summary and significant mean differences

Table 10. EMG increase in the orbicularis oris: ANOVA summary and significant mean differences

Table 11. EMG decrease in the orbicularis oris: ANOVA summary and significant mean differences

Table 12. Intercorrelations of the physiological scores

Table 13. Correlations between memory and arithmetic task performances and physiological scores of the respective (Me and Ar) S2-conditions

Table 14. Correlations between reaction (RT) and pressure (PT) times and physiological scores of Motor Condition

Table 15. Correlations between the ratings of unpleasantness (UN) and difficulty (DI) and physiological scores across conditions

Table 1. Skin conductance: ANOVA summary and significant mean differences

A. First-interval response

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	0.000	3	0.019	.999			
error	0.043	76					
Conditions (C)	0.011	5	4.196	.001	4	.003	sS>Ar
G x C	0.005	15	1.784	.035	11	.057	*(FI: sS,Mo>others)
error	0.003	380			277		

B. Second-interval response

Information (G)	0.003	3	0.471	.704			
error	0.007	76					
Conditions (C)	0.008	5	3.451	.005	4	.009	sS>Se,Me
G x C	0.006	15	2.526	.001	12	.004	
error	0.002	380			315		FI: Mo,Ar>Se,tS
							FI: Me>tS
							PI: Mo>Se
							Mo: FI,PI>SE

C. Third-interval response

Information (G)	0.104	3	2.063	.112			
error	0.051	76					
Conditions (C)	0.160	5	33.476	.000	3	.000	Mo,sS>tS>others Ar>Me>Se
G x C	0.024	15	5.051	.000	10	.000	NI: Mo,sS>others
error	0.005	380			262		NI: Ar,Me>Se
							PI: Mo,sS>Me,tS
							PI: sS>Se
							FI: Mo>sS,Ar
							FI: Se<others
							SE: Mo,sS,tS>others
							sS: SE,NI>FI; NI>PI
							tS: SE>others

* Parenthesized because significant only in the Newman-Keuls test

Table 2. Pulse amplitude: ANOVA summary and significant mean differences

A. First-interval response

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	287.324	3	2.659	.055			
error	108.464	76					
Conditions (C)	16.355	5	0.607	.703	4	.665	
G x C	47.608	15	1.747	.042	13	.052	
error	27.414	380			326		

B. Second-interval response

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	1412.635	3	5.780	.001			SE>NI,FI
error	244.417	76					
Conditions (C)	126.271	5	2.409	.037	4	.050	
G x C	136.537	15	2.594	.001	13	.002	FI: Mo<others Se,Me,sS,Mo: SE>FI Mo: SE>others
error	52.631	380			336		

C. Third-interval response

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	2674.211	3	4.446	.006			NI<PI,SE
error	602.865	76					
Conditions (C)	868.577	5	16.033	.000	4	.000	Ar,Me,Mo<others
G x C	121.263	15	2.248	.005	12	.010	PI: Ar<others FI: Mo<others FI: Me<Se SE: Ar,Me<Se sS: NI,FI<PI Ar: NI<others Mo: FI,NI<PI,SE
error	54.173	380			315		

Table 3. Heart rate: ANOVA summary and significant mean differences

A. First-interval acceleratory peak

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	232.164	3	7.336	.000			SE<others
error	31.690	76					
Conditions (C)	16.049	5	1.692	.136	5	.136	
G x C	19.560	15	2.062	.011	14	.013	PI: Ar>sS,Mo,tS
error	9.486	380			353		FI: Me>sS,Mo
							sS: FI>SE<PI<NI
							Ar: PI>SE
							Me: FI>PI>SE<NI

B. First-interval mean change (from the pretrial level)

Information (G)	127.511	3	5.323	.002			SE<others
error	23.956	76					
Conditions (C)	23.124	5	2.911	.014	4	.022	Ar,Me>tS
G x C	18.684	15	2.352	.003	13	.005	PI: Ar>sS,Mo,Me
error	7.945	380			338		FI: Me>tS,sS
							FI: Mo>tS
							sS: SE<others
							Me: FI>NI,PI>SE
							Ar: PI>SE

C. Second-interval deceleratory peak

Information (G)	19.040	3	1.006	.399			
error	19.113	76					
Conditions (C)	13.403	5	1.946	.088	5	.088	
G x C	12.153	15	1.755	.039	14	.044	PI: Ar,Se>tS,Mo,sS
error	6.924	380			346		PI: Me>sS

D. Second-interval mean change (from the pretrial level)

Information (G)	21.092	3	1.176	.328			
error	18.093	76					
Conditions (C)	24.403	5	3.675	.003	4	.006	Ar>tS
G x C	8.374	15	1.261	.224	13	.235	PI: Ar>sS,tS,Mo
error	6.641	380			337		PI: Me>sS
							Ar: PI>SE

(continues)

Table 3 (continues)

E. Third-interval acceleratory peak

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	148.567	3	2.523	.064			
error	58.888	76					
Conditions (C)	656.310	5	41.042	.000	4	.000	Ar,Mo,Me>Se>sS>tS
G x C	40.611	15	2.540	.001	12	.003	NI: Ar,Me,Mo>Se,sS,tS
error	15.991	380			304		PI: Ar>Me,Mo>Se>tS,sS
							FI: Ar,Me,Mo>Se,sS,tS
							FI: Se>tS
							Se,Ar,Me: SE<others
							Mo: SE<others, NI>PI

F. Third-interval mean change (from the prestimulus level)

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	100.320	3	2.194	.096			
error	45.715	76					
Conditions (C)	898.991	5	61.358	.000	4	.000	Ar,Mo,Me>Se>sS,tS
G x C	40.992	15	2.807	.000	12	.001	NI: Mo>tS,sS,Se
error	14.654	380			309		PI: Ar>tS,sS
							FI: Mo,Ar,Me>sS,tS
							Ar: PI>SE
							Mo: NI>SE

Table 4. Respiratory disturbances: ANOVA summary and significant mean differences

A. Probability during the first-interval

Source	MS	df	F	p	Lambda hat adj. df	p	Newman-Keuls mean comparison (p < .05)
Information (G)	0.130	3	0.825	.484			
error	0.158	76					
Conditions (C)	0.049	5	1.287	.273	5	.273	
G x C	0.031	15	0.806	.683	15	.683	
error	0.039	380			370		

B. Probability during the second-interval

Information (G)	0.312	3	2.213	.093			
error	0.141	76					
Conditions (C)	0.031	5	0.921	.467	4	.452	
G x C	0.056	15	1.651	.059	13	.070	(NI: sS,tS,Mo>others sS,tS,Mo: NI>others)
error	0.034	380			338		

C. Probability during the third-interval

Information (G)	0.334	3	2.786	.047			SE>FI
error	0.120	76					
Conditions (C)	0.303	5	6.972	.000	4	.000	Mo>Ar,Me,Se tS>Ar,Se
G x C	0.091	15	2.107	.010	13	.014	NI: Mo>Ar,Se,Me NI: sS>Me FI: Ar>Me,Se sS: SE,NI>FI,PI Mo: NI>FI
error	0.043	380			330		

Table 5. Duration of the respiratory cycle: ANOVA summary and significant mean differences

A. First-interval

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	5.448	3	1.202	.315			
error	4.534	76					
Conditions (C)	0.233	5	1.815	.109	4	.126	
G x C	0.256	15	1.995	.015	12	.024	(FI: Ar,Me>Mo)
error	0.129	380			300		

B. Second-interval

Information (G)	6.757	3	1.679	.181			
error	4.049	76					
Conditions (C)	0.732	5	7.242	.000	4	.000	tS,sS>Mo,Me sS>Se
G x C	0.116	15	1.157	.312	11	.324	
error	0.101	380			281		

C. Third-interval

Information (G)	9.382	3	2.471	.068			
error	3.796	76					
Conditions (C)	0.564	5	4.370	.001	4	.002	sS,tS>Se
G x C	0.265	15	2.052	.012	12	.020	FI: Me,Se,Ar>Mo
error	0.129	380			296		

Table 6. Blood volume: ANOVA summary and significant mean differences

A. Blood volume increase during S1 -interval

Source	MS	df	F	p	Lambda hat adj. df	p	Newman-Keuls mean comparison (p < .05)
Information (G)	3041.439	3	2.196	.097			
error	1391.448	76					
Conditions (C)	2010.358	5	2.717	.020	5	.020	Ar,Me>Se
G x C	1033.967	15	1.392	.147	14	.154	
error	742.541	380			360		

B. Blood volume decrease during S1 -interval

Information (G)	187.693	3	0.174	.914			
error	1077.253	76					
Conditions (C)	712.058	5	0.612	.691	5	.691	
G x C	2174.815	15	1.870	.025	14	.028	FI: Mo>Ar
error	1163.118	380			360		

C. Blood volume increase during S2 -interval

Information (G)	19413.060	3	14.405	.000			SE>PI>NI,FI
error	1347.694	76					
Conditions (C)	9027.409	5	7.415	.000	4	.000	Ar>sS,tS,Mo,Se
G x C	1603.630	15	1.327	.188	12	.207	FI: Ar>sS,tS,Mo,Se
error	1217.530	380			313		sS,tS,Mo: FI<SE

D. Blood volume decrease during S2 -interval

Information (G)	5228.698	3	3.586	.018			SE>NI,FI
error	1462.021	76					
Conditions (C)	8555.715	5	7.449	.000	4	.000	sS>others but Mo Mo>Ar,Me,Se
G x C	2518.374	15	2.190	.006	13	.010	NI: Mo>Ar,Me,Se
error	1150.170	380			342		FI: Mo>Ar,Se tS>Ar,Me,Se

Table 7. EMG increase in the forearm flexors: ANOVA summary and significant mean differences

A. Probability during the first-interval

Source	MS	df	F	p	Lambda hat adj. df	p	Newman-Keuls mean comparison (p < .05)
Information (G)	1.857	3	9.684	.000			FI,PI>NI,SE
error	0.192	76					
Conditions (C)	0.202	5	5.473	.000	5	.000	Mo>others
G x C	0.098	15	2.663	.001	14	.001	FI: Mo>others
error	0.037	380			345		NI: Mo>tS
							all but Se: FI,PI>SE
							Ar,Mo,tS: FI>NI
B. Probability during the second-interval							
Information (G)	1.735	3	8.771	.000			FI,PI,NI>SE
error	0.198	76					
Conditions (C)	0.608	5	12.647	.000	4	.000	Mo>others
							sS>tS,Me,Se
G x C	0.085	15	1.777	.037	13	.047	FI: Mo>others
error	0.048	380			337		PI: Mo>tS
							NI: Mo>all but sS
							Ar,Me,Mo,sS: FI,PI>SE
							sS,Mo,Me: NI>SE
C. Probability during the third-interval							
Information (G)	2.658	3	17.738	.000			SE<others
error	0.150	76					PI>NI
Conditions (C)	4.391	5	84.263	.000	4	.000	Mo>others
							sS>Me,Ar,Se
G x C	0.161	15	3.092	.000	12	.000	All: Mo>others
error	0.052	380			292		SE: sS>Ar
							Se,Ar,Me,tS: SE<others
							Ar: PI>NI,FI
							sS: PI>SE,FI

Table 8. EMG increase in the frontalis: ANOVA summary and significant mean differences

A. Probability during the first-interval

Source	MS	df	F	p	Lambda hat adj.		Newman-Keuls mean comparison (p < .05)
					df	p	
Information (G)	0.198	3	1.209	.316			
error	0.166	76					
Conditions (C)	0.057	5	0.918	.476	5	.476	
G x C	0.073	15	1.165	.297	14	.301	
error	0.062	380			346		

B. Probability during the second-interval

Information (G)	0.085	3	0.367	.784			
error	0.239	76					
Conditions (C)	0.089	5	1.589	.165	5	.165	
G x C	0.038	15	0.676	.818	14	.807	
error	0.057	380			348		

C. Probability during the third-interval

Information (G)	0.147	3	0.784	.506			
error	0.187	76					
Conditions (C)	0.091	5	1.397	.228	5	.228	
G x C	0.108	15	1.642	.061	14	.066	(sS: NI>FI)
error	0.066	380			367		

Table 9. EMG decrease in the frontalis: ANOVA summary and significant mean differences

A. Probability during the first-interval

Source	MS	df	F	p	Lambda hat adj. df	Lambda hat adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	0.516	3	2.703	.051			
error	0.191	76					
Conditions (C)	0.139	5	2.262	.048	4	.062	(sS,tS: FI>SE)
G x C	0.073	15	1.190	.276	13	.285	
error	0.061	380			335		

B. Probability during the second-interval

Information (G)	0.573	3	3.062	.033			
error	0.187	76					
Conditions (C)	0.041	5	0.684	.636	5	.636	
G x C	0.050	15	0.844	.628	14	.621	
error	0.060	380			351		

C. Probability during the third-interval

Information (G)	2.058	3	12.757	.000			SE<others
error	0.161	76					
Conditions (C)	0.166	5	2.360	.040	5	.040	tS>Mo
G x C	0.081	15	1.169	.302	14	.305	(FI: tS>Mo Se,tS: FI>SE sS: FI,PI>NI,SE Ar: FI,PI,NI>SE Me: FI,PI>SE)
error	0.070	380			346		

Table 10. EMG increase in the orbicularis oris: ANOVA summary and significant mean differences

A. Probability during the first-interval

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	0.120	3	0.942	.425			
error	0.128	76					
Conditions (C)	0.098	5	1.591	.162	5	.162	
G x C	0.109	15	1.774	.036	14	.041	FI: Ar,Me,Mo>sS
error	0.061	380			364		

B. Probability during the second-interval

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	0.102	3	0.782	.507			
error	0.131	76					
Conditions (C)	0.155	5	2.583	.026	5	.026	
G x C	0.164	15	2.749	.001	14	.001	NI: sS>Mo,Se
error	0.060	380			346		FI: sS<Ar,Se,Me
							sS: FI<NI,SE

C. Probability during the third-interval

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	0.683	3	5.722	.001			SE<others
error	0.119	76					
Conditions (C)	0.271	5	3.727	.003	4	.006	Mo>Se,tS
G x C	0.172	15	2.365	.003	13	.005	FI: Mo>tS,sS
error	0.073	380			333		FI: Me>Ar,Se
							Me: FI>SE
							Mo: FI,NI>PI,SE

Table 11. EMG decrease in the orbicularis oris: ANOVA summary and significant mean differences

A. Probability during the first-interval

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	1.468	3	10.345	.000			PI>others
error	0.142	76					
Conditions (C)	0.094	5	1.704	.133	5	.133	
G x C	0.154	15	2.788	.000	14	.001	FI: sS,tS>Ar,Me
error	0.055	380			364		Mo: PI>others
							sS: PI>FI>NI,SE
							Me: PI>FI,NI>SE
							Ar: PI>FI,SE

B. Probability during the second-interval

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	0.856	3	5.394	.002			PI>others
error	0.159	76					
Conditions (C)	0.182	5	2.944	.013	5	.013	tS>Ar,Me,Mo
G x C	0.102	15	1.658	.059	14	.065	(FI: tS>Ar,Me,Se)
error	0.062	380			349		

C. Probability during the third-interval

Source	MS	df	F	p	Lambda hat df	adj. p	Newman-Keuls mean comparison (p < .05)
Information (G)	1.191	3	7.542	.000			FI,PI>SE
error	0.158	76					PI>NI
Conditions (C)	0.182	5	2.947	.013	5	.013	sS>Me,Mo
G x C	0.152	15	2.466	.002	14	.003	FI: sS,tS,Se>Me,Mo
error	0.062	380			361		Se: FI,PI>NI,SE
							Me: PI>others
							Mo: PI>SE,NI
							tS: SE<others

Table 12. Intercorrelations of the physiological scores

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	FPA1																																				
2	SCR1	-11																																			
3	HRp1	-22	05																																		
4	HRm1	-22	08	95																																	
5	Rdis1	05	05	13	09																																
6	Rdur1	09	03	-10	-12	39																															
7	flEMG1	02	-04	08	07	01	04																														
8	frEMGi1	00	00	07	09	04	00	11																													
9	frEMGd1	-07	-01	02	03	00	-02	01	-42																												
10	orEMGi1	-06	-02	18	16	12	06	12	20	-01																											
11	orEMGd1	-06	-07	00	-01	-03	-09	13	00	12	-24																										
12	FPA2	71	-12	-15	-15	09	08	-09	00	-07	-04	-01																									
13	SCR2	-07	34	01	03	00	-02	-03	09	-03	00	-02	-18																								
14	HRp2	02	01	38	45	05	00	10	06	-04	08	-02	-05	02																							
15	HRm2	00	00	53	55	09	00	09	04	-04	10	-03	-07	05	91																						
16	Rdis2	00	02	05	03	54	36	-08	01	05	05	-05	06	03	07	09																					
17	Rdur2	10	02	-11	-14	31	90	02	00	-02	03	-09	11	-01	00	00	38																				
18	flEMG2	-02	-07	05	03	-06	03	66	12	07	13	12	-13	00	08	08	-08	04																			
19	frEMGi2	-01	-02	08	11	-01	-01	10	58	-32	13	00	-01	04	09	08	05	-01	11																		
20	frEMGd2	00	-03	-01	-01	01	00	07	-35	60	00	13	-07	02	-04	-04	-06	-02	10	-50																	
21	orEMGi2	-03	03	07	06	02	00	03	20	-10	54	-26	-06	01	08	09	07	00	05	23	-14																
22	orEMGd2	-06	-12	-01	-04	-05	-08	09	-09	15	-21	64	02	-01	-10	-10	-10	-08	06	-12	16	-43															
23	BVda	01	12	13	14	04	07	03	-01	00	06	-05	-07	08	02	04	00	02	01	-03	00	05	-04														
24	BVca	-13	00	04	03	-02	00	00	03	-03	00	03	-12	05	02	04	01	00	-06	-01	02	01	04	-13													
25	FPA3	46	-02	-05	-06	01	03	01	06	-05	-03	02	59	-11	02	-01	00	07	-04	06	-04	04	-01	-02	02												
26	SCR3	-02	47	-04	-01	03	02	-17	02	-04	-01	-11	-03	25	02	-01	07	03	-09	-06	-04	04	-10	03	00	-15											
27	HRp3	-07	00	48	44	08	-03	09	10	-08	12	-03	-04	-05	27	43	03	-10	11	13	-10	08	00	08	07	-13	-03										
28	HRm3	-13	04	53	56	08	-06	14	09	-02	11	00	-08	00	50	59	02	-10	11	13	-05	03	-01	12	08	-12	-02	73									
29	Rdis3	06	02	03	00	21	17	-03	02	00	09	01	12	-01	02	04	36	20	01	01	-06	-02	05	03	-12	05	07	11	02								
30	Rdur3	13	01	-16	-17	27	85	00	-01	01	00	-05	13	-03	00	-02	32	89	02	-03	00	-03	-05	03	00	07	03	-14	-14	23							
31	flEMG3	02	00	03	01	-07	-06	40	10	05	04	15	-09	00	02	01	-06	-07	52	08	07	00	07	06	00	-04	00	19	10	08	-06						
32	frEMGi3	-01	16	08	09	04	04	06	30	-23	09	-01	-01	02	09	07	10	03	08	38	-27	12	-09	07	-03	00	12	13	13	09	03	09					
33	frEMGd3	01	-10	01	00	-02	-08	11	-23	48	-04	19	-04	-01	-04	-02	-07	-08	13	-24	51	-09	15	03	-07	-02	-10	-08	-03	-02	-09	14	-45				
34	orEMGi3	-04	09	18	20	-01	-06	15	16	-01	27	-12	-15	11	11	13	02	-13	15	17	-04	38	-23	16	-03	-08	08	27	22	10	-10	22	22	-09			
35	orEMGd3	-01	-14	00	-03	01	-06	13	00	08	-16	49	06	-12	-04	-03	-05	-03	09	00	09	-21	48	-09	-04	04	-10	-01	00	-01	-06	07	-08	22	-39		
36	BVdb	13	02	-06	-01	-02	00	-11	04	-10	-02	-04	17	-08	00	00	-01	00	-09	-01	-05	-02	03	13	00	07	10	11	07	-01	01	-08	-02	-06	-07	-09	
37	BVcb	-10	00	-12	-12	-05	-01	-01	-02	04	-04	02	-08	02	-05	-07	05	00	03	05	00	-03	-03	-10	11	-08	12	-06	-11	04	00	04	01	04	00	05	-24
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

Table 13. Correlations between memory and arithmetic task performances and physiological scores of the respective (Me and Ar) S2-conditions

		FI group				All groups			
Variable	Interval	Memory		Arithmetic		Memory		Arithmetic	
		r	p	r	p	r	p	r	p
Pulse amplitude	1	.23	.18	-.00	.50				
Skin conductance	1	-.11	.34	-.22	.19				
Heart rate peak	1	-.03	.46	.11	.34				
Heart rate mean	1	-.04	.43	.13	.30				
Resp.disturb.	1	.13	.30	-.10	.34				
Resp.cycle durat.	1	.05	.42	.19	.22				
Flexor EMG	1	.03	.46	-.14	.29				
Frontal EMG inc.	1	-.35	.08	-.18	.23				
Frontal EMG dec.	1	.20	.22	-.01	.48				
Orbic.EMG inc.	1	-.09	.37	-.05	.43				
Orbic.EMG dec.	1	.21	.21	.16	.26				
Pulse amplitude	2	-.11	.33	.25	.16				
Skin conductance	2	.13	.30	-.14	.30				
Heart rate mean	2	.27	.14	-.06	.41				
Resp.disturb.	2	-.12	.32	-.08	.37				
Resp.cycle durat.	2	-.01	.48	.31	.11				
Flexor EMG	2	.03	.46	-.24	.17				
Frontal EMG inc.	2	-.55	.01	-.11	.34				
Frontal EMG dec.	2	.20	.21	.06	.40				
Orbic.EMG inc.	2	-.45	.03	.07	.39				
Orbic EMD dec.	2	.24	.17	.09	.36				
Blood volume inc.	2	.07	.39	-.21	.20				
Blood volume dec.	2	.08	.38	-.30	.12				
Pulse amplitude	3	.08	.37	.09	.36	.03	.39	.03	.39
Skin conductance	3	-.08	.38	.15	.27	-.04	.37	.03	.40
Heart rate peak	3	-.16	.26	.05	.43	-.11	.19	.10	.21
Heart rate mean	3	-.24	.17	-.03	.46	-.19	.06	.02	.43
Resp.disturb.	3	-.26	.15	-.09	.37	-.06	.33	-.08	.27
Resp.cycle durat.	3	.17	.25	.18	.24	.10	.21	-.09	.24
Flexor EMG	3	-.11	.34	-.11	.33	.07	.28	.01	.46
Frontal EMG inc.	3	-.36	.07	.31	.11	-.15	.11	.24	.02
Frontal EMG dec.	3	.31	.11	-.20	.21	.03	.40	-.14	.13
Orbic EMG inc.	3	-.63	.00	.17	.25	-.08	.26	.11	.20
Orbic EMG dec.	3	.16	.27	.03	.46	.17	.08	.05	.33
Blood volume dec.	3	-.25	.16	-.16	.27	.01	.48	.04	.36
Blood volume inc.	3	.13	.29	-.03	.45	-.14	.12	-.18	.07

Table 14. Correlations between reaction (RT) and pressure (PT) times and physiological scores of Motor Condition

		FI group				Total N			
Variable	Interval	RT		PT		RT		PT	
		r	p	r	p	r	p	r	p
Pulse amplitude	1	-.72	.00	-.46	.07				
Skin conductance	1	.28	.13	.52	.04				
Heart rate peak	1	.48	.02	.51	.05				
Heart rate mean	1	.32	.10	.42	.09				
Resp.disturb.	1	.08	.38	-.05	.43				
Resp.cycle durat.	1	-.14	.30	-.10	.37				
Flexor EMG	1	.19	.23	.13	.35				
Frontal EMG inc.	1	.46	.03	.42	.09				
Frontal EMG dec.	1	-.30	.12	-.31	.16				
Orbic.EMG inc.	1	.33	.09	.75	.00				
Orbic.EMG dec.	1	.20	.21	-.15	.33				
Pulse amplitude	2	-.29	.12	-.49	.05				
Skin conductance	2	-.01	.48	.58	.02				
Heart rate mean	2	.17	.25	.56	.03				
Resp.disturb.	2	-.05	.42	-.24	.22				
Resp.cycle durat.	2	.07	.39	.18	.28				
Flexor EMG	2	.19	.23	.17	.30				
Frontal EMG inc.	2	.34	.08	.36	.12				
Frontal EMG dec.	2	-.57	.01	-.62	.02				
Orbic. EMG inc.	2	.23	.18	.61	.02				
Orbic. EMG dec.	2	.29	.13	-.01	.49				
Blood volume inc.	2	-.15	.27	-.09	.39				
Blood volume dec.	2	.38	.06	.06	.43				
Pulse amplitude	3	-.26	.14	-.47	.06	-.15	.11	-.22	.04
Skin conductance	3	-.31	.11	-.15	.32	-.09	.23	-.05	.35
Heart rate peak	3	.29	.12	.26	.21	.35	.00	.34	.00
Heart rate mean	3	.33	.09	.42	.09	.37	.00	.38	.00
Resp.disturb.	3	.33	.09	.58	.02	.23	.03	.19	.08
Resp.cycle durat.	3	.05	.42	.25	.22	-.10	.20	-.02	.45
Flexor EMG	3	-.41	.05	-.47	.06	-.33	.00	-.30	.01
Frontal EMG inc.	3	.22	.19	.32	.16	.15	.12	.16	.11
Frontal EMG dec.	3	-.40	.05	-.28	.19	-.04	.37	.04	.39
Orbic.EMG inc.	3	-.21	.20	.01	.49	.04	.37	.20	.06
Orbic.EMG dec.	3	-.07	.40	-.23	.23	.04	.37	-.01	.48
Blood volume inc.	3	-.49	.02	-.27	.20	-.35	.00	-.33	.01
Blood volume dec.	3	.19	.23	-.02	.48	.18	.07	.17	.09

Table 15. Correlations between the ratings of unpleasantness (UN) and difficulty (DI) and physiological scores across conditions

		FI group				All groups			
Variable	Interval	UN		DI		UN		DI	
		r	p	r	p	r	p	r	p
Pulse amplitude	1	.06	.26	.12	.11				
Skin conductance	1	.08	.20	-.16	.05				
Heart rate peak	1	-.06	.26	.17	.04				
Heart rate mean	1	-.06	.26	.22	.01				
Resp.disturb.	1	.05	.29	.09	.17				
Resp.cycle durat.	1	.08	.20	.06	.26				
Flexor EMG	1	.03	.37	-.10	.16				
Frontal EMG inc.	1	-.02	.42	.09	.18				
Frontal EMG dec.	1	.09	.17	-.01	.47				
Orbic.EMG inc.	1	-.10	.15	.21	.01				
Orbic.EMG dec.	1	-.05	.30	-.24	.01				
Pulse amplitude	2	-.02	.42	.08	.21				
Skin conductance	2	.04	.35	-.03	.39				
Heart rate mean	2	-.04	.33	.13	.09				
Resp.disturb.	2	-.03	.39	-.01	.44				
Resp.cycle durat.	2	.10	.15	-.03	.38				
Flexor EMG	2	.06	.27	-.24	.00				
Frontal EMG inc.	2	-.01	.46	.08	.22				
Frontal EMG dec.	2	.05	.31	.05	.29				
Orbic.EMG inc.	2	-.04	.35	.15	.06				
Orbic.EMG dec.	2	.03	.40	-.25	.00				
Blood volume inc.	2	.02	.43	.21	.01				
Blood volume dec.	2	-.08	.19	-.12	.11				
Pulse amplitude	3	.00	.49	.02	.43	-.02	.33	-.10	.03
Skin conductance	3	.05	.31	-.19	.03	.18	.00	-.12	.01
Heart rate peak	3	.02	.40	.23	.01	-.05	.18	.26	.00
Heart rate mean	3	-.07	.24	.30	.00	-.07	.09	.32	.00
Resp.disturb.	3	-.04	.35	-.06	.26	.01	.39	-.15	.00
Resp.cycle durat.	3	.02	.41	.03	.36	-.02	.38	-.03	.28
Flexor EMG	3	.05	.31	-.23	.01	.06	.13	-.16	.00
Frontal EMG inc.	3	-.04	.35	-.00	.48	-.06	.13	.04	.24
Frontal EMG dec.	3	.12	.11	-.05	.30	.13	.01	-.13	.00
Orbic.EMG inc.	3	.06	.25	.09	.17	-.05	.18	-.06	.12
Orbic.EMG dec.	3	.07	.23	-.24	.01	.09	.04	-.11	.01
Blood volume inc.	3	.03	.40	.29	.00	.04	.21	.18	.00
Blood volume dec.	3	.01	.44	-.31	.00	.13	.01	-.19	.00