LEARNED HEART-RATE CONTROL AND ITS RELATIONSHIP TO ACCURATE SELF-REPORT

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Abstract

An important debate in visceral learning is whether "awareness" of the response is necessary for learning to occur. Traditional models of visceral learning such as operant conditioning consider awareness of the response unnecessary whereas more recent models such as ideomotor theory, motor skills and problem solving consider it essential. Early research concerning this issue supported the view that awareness of the response was not necessary. However, more recent research has been unable to find instances of heart-rate learning in the absence of accurate self-report. This discrepancy would appear to be due to either inadequate assessment of learning and awareness in the early heart-rate studies, or to procedural differences between early and recent research that affected how or what subjects learned.

Three experiments were conducted to evaluate these two possibilities. Each experiment employed the more thorough assessment methods of the recent research while examining a procedural difference between the early and recent research. In Experiment 1 a group received feedback for increases in heart rate, another group received feedback for decreases in heart rate, and a third group received feedback for both increases and decreases (bidirectional training). Following training, all subjects provided written reports of what they did to produce the response. Average heart rate was found to differ significantly between increase and decrease training conditions and was accompanied by written reports whose contents also differed

significantly between these training conditions. Furthermore, there was a significant positive relationship between magnitude of bidirectional control and veridicality of the reports. No differences were found between the groups trained to produce the response in one direction as compared to the bidirectional group. In Experiment 2 subjects were trained either to increase or decrease heart rate, and were or were not forewarned they would eventually have to produce the response without the aid of feedback ("transfer"). No significant differences were obtained between the forewarned and the not-forewarned groups. However, the relation of response awareness and success at learning was well preserved in both forewarning conditions. In Experiment 3, subjects were trained to produce either increases or decreases in heart rate, but were prohibited from using respiratory or somatomotor activity to solve the feedback problems. In addition, half the subjects were encouraged through instructions and electrode placement to use mental means to influence the feedback. Significantly poorer control and less accurate reports were obtained in the increase group given mental instructions compared to the increase group given the standard instructions. However, significant relationships between self-report and bidirectional control were obtained in all groups.

These experiments demonstrate that the positive relationship between heart-rate learning and accurate self-report is a robust association not dependent upon bidirectional training, forewarning of transfer, constraints on behaviour, or a mentalistic task orientation. This result indicates that the discrepancy between the early research and recent research is likely due to inadequate methods of assessing learning and awareness in the early studies. These results also indicate that cognitive considerations are important determinants of visceral learning, and approaches that assign a role to problem-solving activities in learning are appropriate frameworks for study of the visceral learning process.

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CHAPTER 1: INTRODUCTION

In a typical visceral learning or "biofeedback" experiment, a subject is seated in a chair and has electrodes attached to his body that measure one or more autonomic responses such as heart rate, electrodermal activity or blood pressure. Response activity is recorded by a polygraph and then transferred to a computer that provides the subject with on-line exteroceptive feedback proportional to changes in a particular autonomic response. For example, variations in heart rate might be depicted as changes in the position of a cursor on a visual display or as changes in auditory frequency or loudness. The subject has usually been instructed that his task is to gain consistent control over the autonomic response by developing control over the feedback. The total training session usually lasts about one hour, but may be repeated over a period of several days.

It is now well established that subjects acquire the ability to control their physiological responding as a consequence of such training (Miller, 1978). However, the process by which this control develops is unclear. At least four different models or frameworks for understanding visceral learning exist. The earliest conceptualization of visceral learning, and the model to be presented first, is operant conditioning.

MODELS OF VISCERAL LEARNING

Operant conditioning

Explanation of learned control from the perspective of operant conditioning is straightforward. The principle of operant conditioning states that any response that is followed by a rewarding or "reinforcing" event is more likely to recur in the future. Thus, if the situation has been arranged such that the occurrence of a particular autonomic event such as an increase in heart rate is consistently followed by reward, heart-rate increases will occur more often, which will result in more frequent pairings with reward, which will eventually produce a consistently high heart rate. Responses that tend to co-occur with initial heart-rate changes (e.g. muscle tension) will also increase in frequency due to their occasional pairings with reward, but because they are not as consistently rewarded, their association with heart-rate changes will gradually lessen. The presence of such a response-reinforcer contingency is said to be the only necessary and sufficient condition to establish visceral control. The psychological and/or physiological mechanisms of this process are left unspecified and are not thought to be essential to an understanding of how learning takes place (Black, Cott & Pavloski, 1977).

The development of associations between environmental stimuli and behavioural responses through reward would appear to be an important capability of all organisms with the ability to learn. The explanatory power of operant conditioning is evident in such fields as animal learning (MacKintosh, 1974). But whereas the associative effect of reinforcement is an important feature of learning, it is not the only feature. The parsimony of a strict operant account neglects some determinants of learning that question the adequacy of this model in explaining the development of human autonomic control.

One of these determinants concerns biological constraints. Because the autonomic nervous system serves a homeostatic role, autonomic responses are highly integrated with each other and with other systems. As a result, it is very difficult to achieve highly specific changes in visceral responding through feedback methods, although operant accounts predict otherwise (Kimmel, 1982; Marlin, 1984; Miller, 1978; Miller & Dworkin, 1974). Furthermore, not all responses are equally amenable to control as operant conditioning implies. Yates' (1980) review of the literature indicates that for the large majority of autonomic responses, changes are more readily produced in one direction (either increases or decreases) over the other. Another determinant of learning that is overlooked by a framework consisting of general principles is that of individual differences, a number of which exist in visceral learning (Katkin, Morell, Goldband, Bernstein & Wise, 1982; Lang, 1975; Levenson & Ditto, 1981; Miller, 1978; Qualls & Sheehan, 1981).

The generality of operant conditioning creates other problems. Because no limits are set on operant conditioning's bounds of application, it is able to provide explanations for a wide range of phenomena. Some of these explanations do not appear very compelling, however. This is most apparent in the human case. Although at one level of analysis it is possible to conceptualize human biofeedback training in terms of visceral operants shaped by the rewarding consequences of the feedback, some have suggested that this is not the level that provides the most meaningful or convincing explanation. This description may have legitimacy in the case in which the feedback the subject receives has some natural reinforcing value or biological significance (e.g. shock avoidance, noise termination, association with monetary gain) (Hatch & Gatchel, 1981; Kimmel, 1982), but it is less satisfactory in the more common situation where the reinforcing nature of the feedback is not obvious or very indirect (e.g. visual or auditory signals) and learning still occurs. It seems more plausible here to suggest that feedback serves an informational rather than rewarding role. A more general point concerns the assumption of automaticity that is implicit in operant conditioning. The statement that the presence of a response-reinforcer contingency is the only necessary and sufficient condition for learning implies that the cognitive activities of the subject are peripheral to the learning mechanism. Empirical evidence relevant to this issue will be discussed in greater detail later. Suffice to say at this point that the adequacy of operant conditioning is strained by what we know about the influence of verbal instructions and subject expectancies upon learning across groups with identical feedback contingencies (Bell & Schwartz, 1973; Blanchard, Scott, Young & Edmundson, 1974; Brener, 1974a; Lacroix & Roberts, 1978; Lang, Sroufe & Hastings, 1967).

In an attempt to incorporate some of these above mentioned phenomena, alternate conceptualizations of the visceral learning process have been proposed.

Motor skills

The first is the motor skills analogy. It has been suggested by a number of investigators (Brener, 1974a; Johnston & Lethem, 1981; Lang, 1974; Schwartz, 1974) that "the acquisition of voluntary control over a viscus is a skill......it requires an organized sequence of activities, movements, and symbolic information such as those required to play darts or hit a tennis ball (Lang, 1975, p. 173)". A problem with this approach is that it is not totally clear what the implications of this orientation are or how they differ from operant conditioning (Hatch & Gatchel, 1981). There have been some suggestions that it implies that 1) knowledge of results is vital to learning; 2) control improves with training; 3) the more information provided by the feedback the better is learning; and 4) control becomes more specific with training (from Johnston, 1977). But if this is so, then the evidence does not appear to strongly support such an orientation (Johnston, 1977; cf. Schwartz, Young & Volger, 1976; Williamson & Blanchard, 1979).

Nevertheless, an important advantage of a motor skills approach to visceral learning is the emphasis it gives to important features of visceral control. Rather than focusing on simple stimulus-response contingencies, this approach emphasizes how a response to a particular situation involves a complex integration of information from sensory sources, memory, and context interacting with the functional capabilities of the organism. There is a flexibility of response depending on circumstance because the unit of performance involves larger organizations of activity such as strategies or procedures. The eventual end product in the development of a motor/visceral skill is not an isolated behaviour closely controlled by the presence of a particular stimulus, but an organized program that incorporates economy in performance and flexibility in response.

Ideomotor theory

A third model of visceral learning is Brener's (1974a; 1974b) adaptation of William James (1890) "ideomotor" theory of voluntary action. Brener proposed that providing a subject with exteroceptive feedback for a normally undetectable autonomic activity (e.g. heart-rate changes) allows that subject to detect and recognize afferentation arising from the occurrence of that activity (e.g. peripheral auditory and pressure pulsations, respiratory afferentation, muscular kinesthesia). Through a process called "calibration", exteroceptive feedback (or verbal labels designating such feedback) acquires the ability to elicit a memory of this afferentation, which in turn automatically leads to the performance of the response represented by these sensations. Termination of the act is dependent upon the matching of the afferentation produced by the elicited response with the original afferent pattern. Adjustments are made until differences no longer exist.

Brener's model has had a major impact upon research in visceral learning. This is partly because its incorporation of autonomic control within a "voluntary" framework better explained instructional influences on autonomic control, and partly because the testable implications of this model were fairly clear and appeared to conflict with operant predictions. Unlike operant conditioning and motor skills which made no attempt to provide a mechanism for visceral control, ideomotor theory was very explicit. The feature of this mechanism that has received the most attention is the prediction that "awareness" of the response (as measured by the subject's ability to discriminate its occurrence from its nonoccurrence) is a by-product of learned control of the response, and therefore, substantial relationships should exist between the two phenomena (Brener, 1974b). Evidence concerning this prediction will be reviewed in Chapter 2.

Problem solving

A fourth approach that has been more recently proposed for the study of visceral learning, is that of problem solving (Roberts, Marlin, Keleher & Williams, 1982). This is an orientation that also acknowledges flexibility and the potential contribution of the subject's knowledge to the learning process. Successful production of a particular response in a biofeedback situation is seen as a problem posed by the experimenter which the subject actively attempts to solve. It is recognized that there may not be a direct mapping between the problem as presented by the experimenter ('task statement'), and the subject's conceptualization of the problem ('problem space') (Simon, 1978). The problem space can be influenced by variables such as electrode placements, verbal instructions, feedback procedures, familiarity with similar tasks, physical arrangement of the training situation, and the subject's expectancies, in ways which the experimenter might or might not have anticipated. The problem space will also include, in some form or another, an appreciation of task objectives, legal means by which to accomplish them, and constraints on behaviour. All of these determine the program or strategy that is used by the subject to solve the task. The strategy the subject uses often will be of an analytic nature involving the formulation and testing of hypotheses about the response. Although some activities will be produced fairly haphazardly rather than as a result of a more conscious deliberation, the primary intent of a problem-solving orientation is to suggest that the subject's conceptualization of the task, and the analytic processes he brings to it, are important and often overlooked determinants of visceral control.

OVERVIEW OF THESIS

All four of these models, operant conditioning, motor learning, ideomotor theory, and problem solving, offer quite different descriptions of the learning process. Unfortunately, this does not translate into very many explicit predictive differences. However, one area in which differences do exist concerns the need for, and role of, awareness of the response in autonomic learning.

The assumption of operant conditioning has been that the necessary and sufficient condition required for learning is the simple presence of a response-reinforcer contingency. Awareness of this contingency or of behaviour on which reward is conditional is not thought to be necessary for learning to occur. The view that success at feedback control is associated with awareness of the response has been termed by one researcher working within an operant framework as "at best a speculative hypothesis without much empirical support (Black, Cott, & Pavloski, 1977, p. 123)". The motor skills approach believes awareness of the response to have a greater role. It is implicated in the propositions that knowledge of results is vital to learning and the more information provided by knowledge of results the better is learning (Bilodeau & Bilodeau, 1958; Gill, 1975). It is the refinement, reorganization and execution of the developed skill in the later stages of learning that may not involve awareness to the same extent. Fitts & Posner (1967) in their summary of motor skills research up to 1967, characterize the later phases of skill development as involving a gradual reduction of conscious mediation (see also Harvey & Greer, 1980). Ideomotor theory, as stated earlier, sees response awareness as a necessary by-product of control. In order for control to develop, the internal sensations consequent upon visceral changes have to form an association with some contingent external event. Awareness of these sensations is a by-product of the formation of this association. However, ideomotor theory does not explain why awareness is a concomitant of learning. The problem-solving approach also leads one to expect strong relationships between measures of awareness and control. Because most biofeedback problems have the potential of being easily solved by the use of conscious processes (Roberts et al., 1982), a close association between knowledge and control is to be expected. Unlike Brener's model, however, the means by which control develops, and its expression is not as deterministic. Rather than learning being a process of associative calibration, a problem-solving approach gives a more important role in learning to the analytic behaviour of the subject in his choice of strategies to use, and their evaluation based upon manipulation of the feedback. And rather than the expression of a learned response being closely under stimulus control, there is greater flexibility of response.

Because the presence of response awareness is an issue that differentiates models of the visceral learning process, the relationship between response awareness and response learning has become an extensively studied empirical issue. A review of this evidence in the next chapter shows early research supported the view that visceral learning occurred in the absence of response-awareness. However, more recent research shows a strong association between response awareness and response learning. In light of these conflicting results, this thesis reports the findings of three experiments designed to more adequately address this question and to investigate the basis for this discrepancy. An additional concern of these studies was to assess the impact of certain procedural variables that might affect learning and awareness. The choice of procedural variables was guided by a review of these earlier studies as well as by a problem-solving approach to visceral learning.

CHAPTER 2: EVIDENCE FOR RESPONSE AWARENESS

Before the evidence for response awareness is reviewed, a definition of this term is required. The minimal requirement for response awareness, as it relates to models of visceral learning, is that the subject be reliably able to recognize the occurrence of the response, or to accurately indicate activities that contribute to its occurrence. Response awareness does not require that the subject also be able to describe the purpose of the experiment, the experimenter's contingency, or the exact identity of the response.

There are two bodies of evidence directly relevant to the issue of whether learning can occur without response awareness. One is the discrimination literature, which consists of studies that have examined the ability to reliably discriminate between times when the response is occurring and times when it is not. The second body of evidence consists of studies in which awareness of the response has been assessed by verbal report. Discrimination studies will be discussed first.

DISCRIMINATION

An example of a discrimination procedure is as follows. Subjects are periodically presented with a brief tone that is either coincident with a phasic increase in heart rate or a phasic decrease in the response. When the subject hears the tone, his task is to indicate whether the tone was coincident with a heart-rate increase or a heart-rate decrease. The subject's discrimination ability or "response awareness" is measured by the percentage of his choices that are correct as compared to chance accuracy. This ability is typically assessed prior to feedback training and then again following feedback training, to determine whether successful visceral control is accompanied by a subsequent ability to successfully discriminate the response (see Brener, Ross, Baker & Clemens (1979) for a discussion of this and other methods).

Most discrimination studies have reported that feedback training for a visceral response is subsequently accompanied by a superior ability to discriminate that response (electrodermal response: Keleher & Roberts, 1980; Lacroix, 1977; Lacroix & Gowen, 1981; Stern, 1972; heart rate: Brener, 1977b; Marshall & Epstein, 1978). In those instances in which there have not been significant improvements in discrimination ability after feedback training (e.g. Lacroix & Gowen, 1981), discrimination of the response has still been significantly greater than chance. There is only one report of significant group control not being accompanied by significant group discrimination (Clemens, 1976).

However, this group performance is misleading. When correlations between individual response control and discrimination have been calculated they have usually been nonsignificant or have occurred only for certain training conditions on certain days (electrodermal response: Keleher & Roberts, 1980; Lacroix & Gowen, 1981; heart rate: Clemens, 1976; Clemens & McDonald, 1976; Dale & Anderson, 1978; Lacroix & Gowen, 1981; McFarland, 1975; Whitehead, Drescher, Heiman & Blackwell, 1977; Whitehead & Drescher, 1980; gastrointestinal activity:

Whitehead & Drescher, 1980). Cott, Pavloski & Black (1981) and Keleher (1981) reported several cases in which subjects who succeeded at control of target responding were unable to discriminate instances of the response for which feedback had been given. These findings conflict with theories that maintain that awareness of the response is a necessary by-product of visceral learning (Brener, 1974), or that conscious processing of feedback behaviour is the basis of such learning (Roberts et al., 1982). On the basis of these findings some investigators have argued that awareness is not required for learning at all (Cott et al., 1981). Other investigators, however, have argued that methodological complexities in the discrimination procedure may be responsible for a failure to observe relations between control and awareness at the between-subject level (Brener, 1982; Roberts, 1977; Roberts, Williams, Marlin, Farrell & Imiolo, 1984). Some of these complexities can be illustrated by a further discussion of some discrimination procedures and their pitfalls.

The discrimination method used by McFarland (1975) and McFarland & Campbell (1975) requires the subject to press a button in synchrony with individual heart beats during the testing interval. Discrimination scores are calculated by taking the difference in the number of actual beats and the number of button presses. The problem with this procedure, however, is that good discrimination scores can be obtained simply be pressing at a rate that is known to be close to the average heart rate. Information about the appropriate rate of button-pressing is provided when subjects are told after each discrimination trial how successful they have been. The problem of spurious discrimination is likely to be serious as well in similar procedures that simply require subjects to verbally report their heart rate (e.g. Dale & Anderson, 1978).

Another common discrimination procedure (Keleher & Roberts, 1980; Stern, 1972) is for an experimenter, monitoring autonomic changes, to periodically present a signal and ask the subject whether the signal was associated with the occurrence or nonoccurrence of the response. The problem here is that certain trial parameters such as intertrial interval are not independent of the trial type. For example, a nonoccurrence trial requires a certain period of inactivity. This creates a situation where the subject may base his choice of response occurrence or nonoccurrence, not on response awareness, but on the observation that nonoccurrence trials tend to occur after long intertrial intervals. Again, information on possible trial dependencies of this type is made available when subjects are told of the correctness of their choices after each discrimination trial. Another problem is that random trial sequencing is difficult to achieve when the response continually occurs at a very high rate or a very low rate. Efforts by the experimenter to compensate for this nonrandomness (e.g. never give more than three types of of the same trial in a row), or to entrain their allocation of trials to perceived dependencies in the subject's choice behaviour (Keleher, 1981), may also produce consistencies that can provide a basis for the subject's discrimination performance.

The above examples point to how reports of discrimination ability might be spurious. Spurious discrimination could be expected to diminish the relation of visceral control to response awareness between or within subjects. But this relation can be disturbed by other factors, too. For example, Cott et al., (1981) reported that learned control of occipital alpha was not accompanied by successful discrimination of this response. However, in this study subjects received continuous feedback for alpha trains of up to two minutes in duration during training, whereas 0.5 second epochs of this response were sufficient to trigger discrimination probes on the discrimination test. Furthermore, during discrimination, subjects were not allowed to use activities that might have been associated with alpha during feedback training (e.g. blurring of vision, Mulholland & Peper, 1971). Thus, it is possible that failure at discrimination in this study was due to the discrimination procedure not identifying the aspects of the response subjects became aware of during training (Plotkin, 1981; Roberts, 1977). A similar explanation has been suggested by Brener (1982) for the dissociation between heart-rate control and heart-beat discrimination obtained by Whitehead et al. (1977). The response events that serve as a basis for heart-beat detection (pulsatile sensations deriving from the mechanical consequences of ventricular contraction) may not be the same things subjects learn about when given feedback training for changes in heart rate (somatomotor and respiratory maneuvers).

In conclusion, all of these considerations make discrimination a very problematic procedure for assessing the relationship between response awareness and control. There are significant limitations associated with each particular method and correlations between the methods have been poor (Ross & Brener, 1981; Jones, O'Leary & Pipkin, 1984). Although new discrimination procedures are being attempted to answer some of these problems (Ashton, White & Hodgson, 1979; Katkin, Morell, Goldband, Bernstein & Wise, 1982), it appears unlikely that there will be a quick or simple resolution of these issues. In view of these difficulties, Roberts & Marlin (1979) have suggested that the issue of response awareness might be better addressed by the analysis of subjects' verbal reports of what they did to produce feedback events. The next section reviews studies that have employed the verbal report as the measure of response awareness.

VERBAL REPORTS

Studies that have employed the verbal report can be divided into two groups: early studies and recent research.

Early studies

The term "early studies" refers to experiments conducted between 1962-1973 that assessed response awareness by asking the subject about the response following successful biofeedback training. In some of these studies the purpose of the experiment was concealed to determine whether autonomic changes could be conditioned without subjects being aware they were undergoing conditioning, or being able to report a relationship between occurrence of the reinforcer and changes in their behaviour. A lack of awareness was reported in the majority of these studies (electrodermal response: Crider, Shapiro & Tursky, 1966; Fowler & Kimmel, 1962; Gavalas, 1967; Greene & Sutor, 1971; Johnson & Schwartz (Group NI), 1967; Kimmel & Kimmel, 1963; Okita, 1971; Rice, 1966; Schell & Grings, 1970; Schwartz & Johnson, 1969) (heart rate: Brener, 1966;

Frazier, 1966). In other studies, subjects were made aware they were undergoing conditioning but were not told the identity of the response being trained. These studies also found subjects unable to accurately describe what activities were related to presentation of the feedback or reinforcement (electrodermal response: Johnson & Schwartz (Group I), 1967; Shapiro & Watanabe, 1971; Shean, 1970) (heart rate: Brener & Hothersall, 1966; Cohen, 1973; Engel & Chism, 1967; Engel & Hansen, 1966; Finley, 1970; Levene, Engel & Pearson, 1968; Shapiro, Tursky & Schwartz, 1970) (blood pressure: Shapiro, Schwartz & Tursky, 1972; Shapiro, Tursky, Gershon & Stern, 1969; Shapiro, Tursky & Schwartz, 1970) (pupillary change: Prather & Berry, 1973). Table 1 lists all studies reporting autonomic control in unaware subjects (see Table 1).

Statements made by several researchers during this early period reflect the prevailing view. For example, Engel (1972) summarized his experience as follows.

> "I began this research about 1962, and I have asked every subject whom I ever tested the same question: "What did you do?" "How did you do it?" And after ten years of this nonsense I finally recognized this year how silly these questions are.........if learned cardiac control is a form of motor learning as I believe is the case, then why should someone be able to describe the details of his performance during the early stages of learning?..........It is a small wonder that I have not been able to find any consistency among the stories the subjects have told me. I am certain that they do not know what they are doing, and that they are just making

Table 1a: Studies reporting increase and/or decrease heart-rate control in "unaware" subjects

STUDY	Training Condition[a] I	D	I/D	Forewarning of Transfer or Verbal Reports[b]	Constraints[c]	Task Orientation[d]	Awareness
Frazier (1966)	X			no	none	-unclear -distractor task	"The goal of conditioning without awareness appeared to be met. There was no evidence that any S became aware of the...contingency"
Brener (1966)	X	X		no	none	-unclear -misleading instructions	"In no case did a S report that the ...stimuli were correlated with any aspect of her behavior...[or] ...her pulse."
Brener & Hothersall (1966)			X	no	-movement	-control response -misleading instructions	-no S discovered HR to be the response and only 1/5 showed evidence of veridical knowledge
Engel & Hansen(1966)		X		no	-respir.	-control response -misleading instructions	-reported that although some experimental S's correctly guessed the response &/or reported veridical strategies, this pattern was also observed for yoked control S's -also noted that S's who did guess the correct response tended to be the poorer learners
Engel & Chism(1967b)	X			no	-respir.	-control response -misleading instructions	
Levene, Engel & Pearson (1968)			X	no	-movement -respir.	-control response	-only one S guessed HR and another guessed "blood flow" -these two were the poorest decrease learners -S's unaware of breathing changes
Shapiro, Tursky & Schwartz (1970)	X	X		no	-movement -respir. -m. tension	-control response	-no consistent verbal report, differences between the two groups -note, however, some tendency to correctly guess group (up vs down)
Finley (1970)		X		yes	-movement -respir. -m. tension	-control response	"none of the 20 S's was aware that cardiac activity was involved in any way"
Cohen (1973)	X	X		no	none	-control response	-no consistent verbal report differences between the two groups -however, a few increase S's thought respiration was being trained

Table 1b: Studies reporting increase and/or decrease electrodermal control in "unaware" subjects

STUDY	Training Condition[a] I	D	I/D	Forewarning of Transfer or Verbal Reports[b]	Constraints[c]	Task Orientation[d]	Awareness
Fowler & Kimmel (1962)	X			no	-movement -respir. -m. tension	-unclear	-5/40 S's were eliminated from the analysis because they reported that the light may have been correlated with some aspect of their behaviour
Kimmel & Kimmel (1963)	X			no	-movement -respir. -m. tension	-unclear	-the postexperimental interview eliminated any S who was able to "verbalize awareness of the contingency of reinforcement upon something they might have done"
Crider, Shapiro & Tursky (1966) (experiment #4)	X			no	-movement	-unclear -misleading instructions	"we have been unable to separate S's into contingent and noncontingent groups on the basis of postexperimental interviews"
Rice (1966)	X			no	-respir. -m. tension	-unclear	"limited postexperimental questioning failed to find anyone who could state an awareness of the reinforcement contingency"
Gavalas (1967) (experiment #2)	X			no	-movement	-unclear -distractor task	"none of the S's reported any knowledge of the purpose of the experiment or believed that they could predict or control occurrence of the reinforcer"
Johnson & Schwartz (1967) (Groups I and NI)		X		no	-movement	I -control response + m.instruct. NI -unclear	-only 10/32 S's indicated that their behaviour may have influenced the occurrence of the reinforcer -of these S's half were in the noncontingent group
Schwartz & Johnson (1969)	X			no	none	-unclear -misleading instructions	-2/10 S's in the contingent group and 2/10 S's in the noncontingent group indicated their behaviour may have influenced the occurrence of the reinforcer
Schell & Grings (1970)	X			no	-movement -respir.	-unclear	"no S in either group stated that there was any means by which he seemed to be able to prevent the shock"
Shean (1970)			X	yes	-movement -respir. -m. tension	-control response -distractor task	-1/14 S's showed veridical knowledge -11/14 S's incorrectly believed that that the shock was related to some feature of the words in a concurrent verbal task
Greene & Sutor(1971)			X	no	-movement	-unclear -misleading instructions	-1/8 S's indicated that breathing might have influenced the reinforcer "all other S's gave no indication that they might have influenced their GSR in any manner"
Okita (1971)	X			no	-movement	-unclear	"from the analysis of the questionnaire, it was shown that the S's had not become aware of the avoidance procedure"
Shapiro & Watanabe (1971)	X			no	-movement -respir. -m. tension	-unclear	"the relationships between the verbal reports and the specific patterns of SPR activity were not consistent from S to S or session to session"

Table 1c: Studies reporting increase and/or decrease blood-pressure control in "unaware" subjects

STUDY	Training Condition[a] I	D	I/D	Forewarning of Transfer or Verbal Reports[b]	Constraints[c]	Task Orientation[d]	Awareness
Shapiro, Tursky, Gershon & Stern (1969)	X	X		no	-movement -respir. -m. tension	-control response	"with one or two exceptions, S's said they had no control over the [light] and no knowledge of what specific... function we were trying to condition"
Shapiro, Tursky & Schwartz (1970)	X	X	X	no	-movement -respir. -m. tension	-control response	"verbal reports of the S's were similar to those obtained in prior research and were not consistently related to experimental condition"
Shapiro, Schwartz & Tursky (1972)	X	X		no	-movement -respir. -m. tension	-control response	"on a variety of questions no consistent differences in reports of subjective or physical state were found between...conditions"

Table 1d: Studies reporting increase and/or decrease pupillary size in "unaware" subjects

STUDY	Training Condition[a] I	D	I/D	Forewarning of Transfer or Verbal Reports[b]	Constraints[c]	Task Orientation[d]	Awareness
Prather & Berry (1973)			X	no	-m. tension -blink rate	-control response	-how did you produce the reinforcer? 6=did not know, 3=something to do with the eye, 2=something to do with the tones, 1=concentrating hard

[a] I=increase training, D=decrease training, I/D=increase and decrease training

[b] refers to whether the subject was encouraged to develop an objective appreciation of the important components of his response state by such things as informing him that he would eventually be asked to transfer or provide a verbal report

[c] refers to instructed and/or enforced constraints on behaviour (movement, respiration, muscle tension)

[d] refers to whether subjects were informed that the experiment required them to control an unnamed response, or whether the nature of the experiment was unclear and/or disguised by misleading instructions or a distractor task

up stories to please me (Engel, 1972, pp.207-208)."

Yates, in a comprehensive textbook on biofeedback published in 1980, offered a similar description of biofeedback learning based on this early research. He wrote:

"When the biofeedback research worker or clinician conducts an experiment or carries out treatment using biofeedback displays, it is commonly observed by the experimenter or clinician that he is unable to provide the subject or patient with precise instructions as to how control may be achieved over the function that is being studied. Following the completion of the experiment or treatment, and assuming some success in obtaining control over the function, it is equally commonly observed by the subjects or patients that they are unable to describe what they did to achieve control (Yates, 1980, p.393)".

Similar viewpoints have been expressed by Kimmel (1974, p. 329) and Blanchard & Epstein (1978, pp.37-38), among others.

Reasons to question this view that learning occurs without awareness can be found in the early literature, however. A minority of subjects in the studies by Kimmel were eliminated <u>because</u> they had become aware of the response-reinforcer contingency (Kimmel, 1974). Murray & Katkin (1968) reanalysed the verbal reports in the experiments by Engel & Chism (1967) and Engel & Hansen (1966) and found a greater degree of differential report than Engel acknowledged. Berger (1973) found no evidence of heart-rate control "without awareness of some relevant contingency". Shapiro, Tursky & Schwartz (1970) reported a tendency for subjects receiving heart-rate feedback to correctly guess whether they were in the increase or decrease group. Schwartz, Shapiro & Tursky (1971) noted that subjects trained to simultaneously increase blood pressure and heart rate reported "more active mental and task involvement" than subjects trained to simultaneously decrease these activities (although this observation was qualified by noting that these data are too variable to warrant firm conclusions). Schwartz (1972) reported that a group trained to produce lowered blood pressure and heart rate reported more things associated with relaxation than the other three conditions. Finally, in a study in which heart rate was trained, Blanchard, Scott, Young & Edmundson (1974) observed reports of relaxation for heart-rate decreases and reports of fear, anxiety, anger, aggression, arousal, sex, tension and excitement for heart-rate increases, in groups that were not told that heart rate was the target response. Nevertheless, Blanchard later stated that "we tend to agree with Engel (1972) that it is futile to ask subjects how they do it (Blanchard & Epstein, 1978, p.38)".

Studies purporting to show learning without awareness have also been criticized on a number of methodological grounds by several researchers (Brewer, 1974; Dulany, 1962; Ericsson & Simon, 1980; Roberts & Marlin, 1979; Spielberger & DeNike, 1966).

One issue concerns the actual method of assessment. The administration and evaluation of verbal reports has generally been haphazard and unsystematic. As David Shapiro describes it "Many investigators have collected data about cognitive factors in biofeedback studies. Most have been skeptical about the value of subjective reports. We usually file such data away along with other physiological measures that we take out of habit but don't analyze very carefully....(Shapiro, 1977, p.222)". The evaluation of these reports has rarely been well controlled or involved any sort of statistical assessment. More typically, the experimenter will have judged that awareness was or was not present using his or her own subjective criteria as Table 3 describes. More importantly, however, this lack of quantification does not permit correlations to be computed that would examine the unanswered question of whether there is a relationship between self-report and control on an individual basis. A failure to obtain group differences in awareness does not necessarily mean that there is no relationship within each group between magnitude of control and the presence of awareness.

Another issue is the restrictive criteria by which awareness was assessed. A common measure of awareness in the early studies was whether subjects were able to specify the autonomic response being trained, and to state the precise relation of this response to feedback events. Considering that some subjects may never have even heard of the response being trained, this does not seem to be a reasonable criterion. Another objection, however, is that there are a number of salient, respiratory, somatomotor and cognitive correlates of visceral activities that have been widely reported in studies of biofeedback and are known to contribute to the occurrence of the response (Marlin, 1984; McCanne & Iennarella, 1980; Newlin & Levenson, 1978; Obrist, 1981; Obrist, Galosy, Lawler, Gaebelein, Howard & Shanks, 1975; Yates, 1980). It seems inappropriate to call someone unaware when he can correctly report concomitants of the response that are systematically related to presentation or control of the reinforcement/feedback. Knowledge of these concomitant activities was not commonly examined in these early studies (Table 1). Assessments of awareness that have required knowledge of only one particular concomitant that may or may not have been employed, (e.g. Crider et al., 1966), are too restrictive for this same reason.

Another problem concerns response bias in the verbal report. For example, as indicated in Table 1, it was a common practise to instruct subjects to avoid moving around, tensing muscles or to alter breathing. This was done to control for the possibility that autonomic ("involuntary") activity was being mediated by somatomotor or respiratory ("voluntary") behaviour. The frequent use of cryptic experimental procedures was similarly intended to control for cognitive and somatomotor mediation. As will be argued later in Chapter 5, the effectiveness of these procedures in controlling for respiratory, somatomotor and cognitive behaviour is suspect, as it is now well established that most autonomic activities are subject to very little alteration in the absence of such concomitant changes for the short training periods common in these studies (Marlin, 1984; Obrist, 1981).[1] The point here is that instructions prohibiting the use of activities that prove to be effective in attaining control are likely to discourage subjects from reporting these activities even when they were used. Another procedure likely to bias the subject's report is providing misinformation about the nature of the response or the experiment. Examples of this are informing subjects that the response is not related to breathing (Engel & Chism, 1967; Engel & Hansen, 1966) and that the purpose of the experiment is to determine how much shock can be tolerated (Shean, 1970). Studies that include prominent but irrelevant concurrent tasks, such as reading a list of nonsense syllables (Gavalas, 1967), are likely to promote nonveridical reporting for the same reasons (for other examples of this see Brener, 1966; Frazier, 1966; and Johnson & Schwartz, 1967; 1969).

A final problem relevant to both the discrimination and verbal report studies concerns the issue of learning. Studies have reported learning without awareness often without demonstrating that the obtained autonomic control represents learned control. For learning to have occurred, it is necessary to demonstrate that information about the response has been retained as a result of experience with the feedback. There are at least two other ways in which autonomic changes can be produced that do not involve learning. The first is where the experimental procedures have biased the subject's approach to the task in a way that prompts or elicits the appropriate autonomic changes. For example, subjects instructed to produce heart-rate increases or decreases will usually be able to do so in the absence of feedback training (e.g. Bergman & Johnson, 1971). This is apparently because these instructions elicit generalized behavioural arousal or relaxation (Brener, 1974a; Lacroix & Roberts, 1978). This is a situation where appropriate autonomic changes have been immediately elicited as a component of a global behavioural change, rather than as a product of extended experience with the feedback or learning. Confounding of feedback and increase and/or decrease instructions has occurred in most discrimination studies and it is possible that elicited rather than learned effects were responsible for some of the instances where control of the response was obtained without success at discrimination (Keleher, 1981).

In a similar manner, less obvious aspects of the experimental procedure may elicit the appropriate autonomic changes without feedback learning. For example, there is evidence that a feedback display that moves up for increase trials and down for decrease trials produces better control than one that goes down for increases and up for decreases (Reeves & Shapiro, 1982). Similarly, a feedback display that goes on for increase trials and off for decrease trials produces better control than a display that does the reverse (Bouchard & Corson, 1976). These displays apparently bias the subjects toward activity or inactivity, and this factor affects the magnitude of control observed under feedback conditions. There are a number of discrimination and verbal report studies that suffer from these confounds (e.g. Brener & Hothersall, 1966; Levene, Engel & Pearson, 1968; Shean, 1970; Whitehead et al., 1977). Response learning cannot be inferred in any study such as these that does not have identical instructions and feedback displays for both training conditions.

A second source of autonomic changes that do not involve learning has been termed "autoregulatory", "cybernetic", or "stimulus-driven" effects (Roberts et al, 1984; Schwartz, 1979). According to this approach, contingent feedback provides information that can automatically regulate the system without any conscious effort on the part of the subject. The introduction of feedback creates a closed feedback loop which immediately and automatically produces autonomic changes, the direction of which depends upon whether the feedback is contingent upon increases or decreases. With the removal of the feedback, the feedback loop is opened and the effect dissipates. Examples of this phenomenon appear to have been reported for occipital alpha (Mulholland, 1977), spontaneous electrodermal responding (Roberts, Lacroix & Wright, 1974) and heart rate (Bason & Celler, 1972a,b). These effects show that feedback from the response is influencing effector activity, but they do not require that information about the response has been retained as a consequence of training experience. There is no evidence that experience with the feedback has enabled a performance capability that was not present prior to feedback training.

The extent to which these autoregulatory or stimulus-driven effects have occurred in the early studies is unknown. One way to distinguish autonomic changes that are due to learning and are under the subject's control from the above effects is to assess the ability of the subject to produce the response in the absence of feedback. Only a minority of the above mentioned studies have used this or other procedures to assess a memory of the response.

Recent research

All of these problems with studies employing verbal reports provided sufficient justification to examine whether awareness of the response could be obtained using a less restrictive criterion for assessing awareness; more rigorous assessment of learning; more neutral experimental procedures; and a statistical analysis of the verbal reports and their relationship to control that included correlations.

Two experiments reported by Roberts, Williams, Marlin, Farrell & Imiolo (1984) were conducted for this purpose. The two experiments differed only with regard to the visceral response that was trained (increases and decreases in heart rate in Experiment 1; lateralized changes in palmar skin conductance in Experiment 2). To illustrate the rationale of these studies, the first experiment which dealt with heart rate will be described.

Briefly, the procedure for feedback training of heart rate in this study was as follows. Subjects were told that they would be trained to produce "two physiological responses that were not normally thought of as being controlled voluntarily". The responses were identified only as "Response A" and "Response B", and the identity of the responses was further obscured by placing electrodes on a number of different locations on the body. Twenty feedback trials, each 30 seconds long, were given during a single session of training. Half of these trials were designated as "A" trials on which Response A was to be produced, and the remainder were designated as "B" trials on which Response B was to be produced. Trials were indicated to the subject by presentation of a televised display containing the letter A or B in the upper right hand quadrant plus a feedback dash that moved in a vertical plane in accordance with heart-rate changes. Subjects were instructed to use any means they could to move the feedback dash in the direction of the letter on A and B trials. For some subjects, success feedback was contingent upon the production of heart-rate increases on A trials and heart-rate decreases on B trials, whereas for the remaining subjects the relation of visceral target (increase or decrease heart rate) to trial cue (the letter A or B) was reversed. Successful production of the required responses produced upward movements of the feedback dash on both trial types. Feedback trials were followed by a series of A and B trials on which subjects were asked to produce the required responses, but exteroceptive feedback was removed (designated here as "transfer" trials). Now, it will be appreciated that because A and B feedback trials differed only with regard to the response for which feedback was given (an increase or decrease in heart rate), a statistically significant difference in heart rate on increase versus decrease trials necessitates that response information identified by feedback contributed to performance on the task. Progressive development of cardiac differentiation between trial type over the course of training further implies that a memory for this response information had accumulated. Successful transfer following training indicates that access to this memory was not feedback dependent. In this way, statistical comparison of performance on A and B trials permitted an assessment of whether response learning had taken place. Decisions were possible at the level of individual subjects, because each subject experienced both A and B feedback (and transfer) trials.

Response awareness was assessed in the following manner. Upon completion of the final block of transfer trials, subjects were asked to describe in open-ended written reports what they did to produce Response A and Response B. These reports were subsequently given to ten judges whose task was to decide, on the basis of the activities the subjects mentioned, whether the subject had been trained to increase heart-rate on A trials and decrease it on B trials, or the reverse. Specifically, judges were told that increases in heart rate tend to be associated with increases in somatomotor and respiratory activity, whereas decreases in heart rate tend to be associated with somatomotor quiescence and slowed breathing (Obrist, Galosy, Lawler, Gaebelein, Howard & Shanks, 1975; Roberts, 1978). However, judges were not required to use these rules if they discerned an alternative basis on which to assign verbal reports to training condition. Now, it will be appreciated that assignment of the reports to correct training condition at greater than chance levels could only mean that subjects were aware of and mentioned at least one activity contributing to production of the response in their verbal reports, because in the absence of this effect there was no way judges could have correctly performed their task.[2] The question was, could the judges perform this task, and if so, how would the assignment of reports of individual subjects relate to their learning performance?

The results of the experiment were as follows. Significant differentiation of the response between trial types (increase and decrease) in both training and transfer was accompanied by open-ended reports that were also significantly differentiable. In addition, there was a significant positive correlation between the proportion of judges who correctly assigned an individual subject's report to training condition and the magnitude of bidirectional control (decrease performance subtracted from increase performance) evidenced in both training and transfer. There was no subject in this experiment who achieved significant bidirectional control of the response in the absence of accurate self-report. This pattern of findings was the same in the second study in which lateralized changes in skin conductance were trained instead of increases and decreases in heart rate. Thus, unlike early studies of response awareness in biofeedback, learning without awareness was not observed.

The studies of Roberts et al. (1984) provided the point of departure for the present research. There is a discrepancy between the results of earlier studies that reported no relationship between response awareness and autonomic control and this research which found no evidence of learning without awareness. Two possibilities exist. The first is that response awareness was present and related to learning in these earlier studies, but the assessment procedures used to determine this were inadequate. The second possibility is that under certain circumstances learning can occur without awareness, and that procedural differences between the early studies and Roberts et al. (1984) are responsible for discrepant results. There are many differences between the procedures in the early studies and those used by Roberts et al. (1984). However, some variables may be more important than others because of the possibility that they may influence the subject's learning strategy and acquisition of knowledge. These variables include: whether subjects are trained to produce the response in both directions or only in one; whether subjects are given forewarning and practise at transfer or not; whether constraints on somatomotor and respiratory behaviour are included; and whether instructions with regard to the utility of various response strategies are neutral, or misleading. Table 1 lists these variables and indicates for each earlier study how they were used.

The purpose of this thesis was to investigate the basis for discrepant findings with respect to response awareness in visceral learning. This was done by examining the impact of the above described variables on learning and awareness in a series of three experiments. The first two experiments looked at variables that might have influenced the subject's learning strategy, whereas the third experiment examined response awareness in two task environments that approximate those used in the early research. If, with the use of the more thorough assessment procedures contained in Roberts et al. (1984), response awareness occurred and was strongly related to control, it could be concluded that assessment was inadequate in these earlier studies. If, however, response awareness did not occur, it would suggest that learning without awareness is possible and that there are important procedural variables that determine this result. The focus of these three experiments was restricted to the heart-rate response because this is the response where the strongest statements concerning lack of subject awareness have been made, and because the behavioural concomitants of heart-rate changes are better established (Marlin, 1984). Methods for assessing response learning and response awareness were similar to those of Roberts et al. (1984).

CHAPTER 3: EXPERIMENT 1

Experiment 1 had two objectives. The first was to replicate the findings of Roberts et al. (1984). The second objective was to investigate whether the open-ended reports would still be correctly assigned to training condition when subjects were trained on one response alone. The majority of the earlier studies employed unidirectional training, that is, training for increases in the response or decreases in the response, but not both (Table 1). All subjects in Roberts et al. (1984), on the other hand, were trained to produce the response in both directions.

It is possible that the contrast provided by training on two opposite and incompatible responses may facilitate learning in comparison to groups trained on only one response. The behavioural strategy that a subject trained on one response uses to produce feedback events may include a number of ineffective components among the effective ones because the ineffective components do not interfere with the production of the desired visceral changes. Subjects training on two opposite responses, on the other hand, will discover that certain activities useful for one response make the feedback go in the wrong direction for the other response. By virtue of their influence on both responses, these activities may be preferentially attended to and utilized. Because activities with this feature are more likely to be useful and veridical than activities without this feature, both control and veridical reporting may be facilitated.

Examples of this type of phenomenon are found in various literatures. In concept formation (Wells, 1967) and discrimination learning (Rieber, 1966) simultaneous presentation of one instance and one noninstance of the concept produces faster learning than simultaneous presentation of two instances or two noninstances. There are also longer term effects of receiving training in contrast-like situations. For example, Duncan (1958) found that a lever-moving task transferred to a slightly different context best when there was training on a number of different lever-moving tasks rather than training on just the one that was tested. Nitsch (1977) similarly found that a concept transferred to new situations best when it was trained in a varied context. The importance of varied context is invoked in Gestaltist explanations of functional fixedness (Katona, 1940); operant explanations of the partial reinforcement effect and spontaneous recovery (e.g. Estes, 1955); and current accounts of the "lag effect" in recall of previously presented items (Melton, 1970; Hintzman, 1974).

Specifically, then, Experiment 1 involved three groups equated for total amount of feedback training for heart-rate changes. One group was trained to increase heart rate (INC), one group was trained to decrease heart rate (DEC) and one group was trained to do both (INC/DEC). If there are beneficial effects of receiving training on two responses rather than one response then they might be observed in any of the following in the INC/DEC group: greater magnitude of heart-rate control in both training and transfer; more frequent report of veridical strategies in the open-ended reports and other self-report measures; and possibly stronger correlations between heart-rate control and these measures of response awareness.

METHOD

Subjects

Forty-eight male volunteers from the McMaster University community and local high schools, aged 15 to 39 (*M* = 19.2), received either $3.00 per hour or course credit for their participation. All subjects were screened with a medical interview to exclude those with physiological disorders and those with previous training in biofeedback. There were 12 subjects in the INC group, 12 subjects in the DEC group and 24 subjects in the INC/DEC group.

Apparatus

Training was carried out in an electrically shielded, dimly lit, sound deadened room. A padded armchair was placed in the centre of a 2m x 3m carpetted enclosure formed by curtains suspended from the ceiling. The subject sat facing a Toshiba C990C colour monitor (screen size 30 cm x 40 cm) situated 1.2m away at eye level, upon which the feedback display appeared.

The feedback display as shown in Figure 1 consisted of trial cues (the letters A and B) that designated the current trial type, a fixed horizontal line that corresponded to the subject's interbeat interval (IBI) just prior to presentation of the feedback, and a vertical dash that moved in accordance with IBI changes from the pretrial measure. The trial cues appeared on the upper right hand quadrant of the screen, the horizontal line was situated just below the centre of the screen, and the feedback dash moved in a vertical plane

Figure 1. Feedback Display. The horizontal line remained fixed in place and represented the level of the last pretrial cardiac measure prior to presentation of the feedback. The vertical dash moved up and down in accordance with cardiac changes during the trial period. Trial type was designated by the alphabetic character (A or B) displayed in the upper right-hand quadrant of the screen.

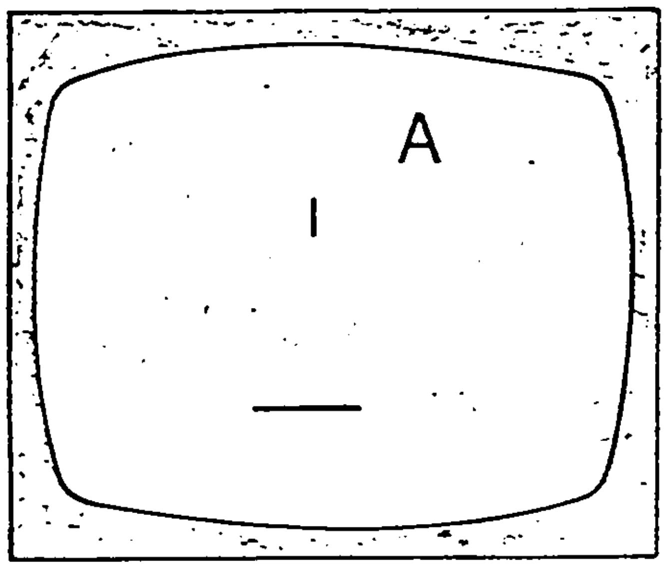


Figure 1

located slightly to the left of the trial cue. Feedback was updated with every heart beat.

Timing, trial sequencing and data recording were controlled on-line by a PDP-11/03 computer. The feedback display was generated by an Apple II computer in the high resolution graphics mode. Parameters for the display were calculated by the PDP-11 and transmitted to the Apple via an RS-232 serial interface. A Beckman Type R polygraph operating at a chart speed of 1 mm/sec was used to monitor the subject's electrophysiological signals throughout the experiment. The polygraph was connected to the PDP-11 by means of an A/D converter. Sampling of physiological channels occurred every 125 msec with the exception of skin conductance which was sampled at 250 msec intervals.

Electrophysiological Recording

All electrode sites were first cleaned with isopropyl alcohol and rubbed with electrode paste. The reference site for skin conductance (SC) was lightly abraded with sandpaper to reduce epidermal resistance.

Cardiac activity was measured by two Beckman Ag/AgCl surface electrodes (15 mm diameter) filled with Beckman Electrolytic paste and placed over the sternum and lower left rib cage. The R-wave of the electrocardiogram was amplified and fed to a digital circuit which discriminated the R-wave from occasional muscle and movement artifact. Discrimination of the R-wave activated a Schmidt trigger on the clock of the PDP-11 which allowed for the continuous recording of successive interbeat intervals (IBI) to the nearest millisecond. Interbeat intervals that were not within pre-established parameters of 300 and

1500 msecs were rejected by the computer as artifact.

Forearm electromyographic activity (EMG) was recorded by means of two Beckman Ag/AgCl surface electrodes (15 mm diameter) filled with electrolytic paste and placed over the ventral surface of the right forearm as described by Lippold (1967). Electrode sites were chosen so as to be sensitive to movements of the fingers. The signal from these electrodes was fed through a Beckman AC/DC coupler (9806A) set to an RC constant of .03 secs with an amplifier gain of 40 mv/cm. Preamplifier output was amplified (x 50) and rectified and sent to the A/D converter.

Gross body movement (MVT) was recorded by means of an inflated cushion concealed in the seat of the subject's chair. The air valve of the cushion was connected to a Beckman 9853A pressure coupler. The cushion was inflated to 25 mm Hg and the coupler calibrated to 1 mm Hg/mv. Preamplifier output was amplified (x 5) and rectified before being sent to the A/D converter.

Respiration was recorded by means of a mercury filled strain gauge (Parks Electronics Laboratory) encircling the subject's upper torso. A Beckman mercury gauge coupler (9875B) measured expansion of the gauge with each respiratory cycle. This signal was subject to post-amplification (x 5) before being sent to the A/D converter. Mean respiratory amplitude (RA), frequency (RF), and volume (RV) (area under the respiratory envelope) were calculated by the computer from this signal using the methods of Marlin (1984).

Skin conductance (SC) was recorded from the hypothenar eminence of both hands through Beckman Ag/AgCl surface electrodes (15 mm diameter). The reference sites were placed on the ventral surface of each wrist. Active and reference electrodes were filled with a paste containing .1M NaCl mixed with Parke Davis Unibase in a ratio of 2.5 : 1 by volume. Contact with the skin was through an opening 10 mm in diameter. Skin conductance was measured as the current generated by a 500 mv DC source applied between the reference and active sites through a series resistance of 2K-ohms. Recordings were taken through a Beckman AC/DC coupler (9806A) set in the DC mode. A calibrated zero-suppression circuit was used to suppress and retain the tonic level. This signal was subject to post-amplification (x 5) before being sent to the A/D converter.

Inactive Beckman Ag/AgCl electrodes were attached to the subject's upper left and upper right forehead (10 mm diameter) and to the subject's left forearm (15 mm diameter). In addition, an inactive thermister (Yellow Springs model YS1429) was taped to each palm.

Procedure

Upon entering the reception area the subject was told that he would be taught to control either one or two physiological responses that were not normally thought of as being controlled voluntarily. It was stated that subjects would not be told what the response(s) were because we had reason to believe this might interfere with their performance (Lacroix & Roberts, 1978). General instructions also indicated that the procedures were painless but subjects were free to withdraw at any time. Conversation past this point was kept to a minimum. A brief medical interview was then given (Appendix A) and recording electrodes attached.

The subject was then taken to an adjoining experimental chamber and seated in the chair facing the television screen. The electrodes were plugged into connections located on both sides of the chair and the physiological recordings were examined on the polygraph located in the adjoining control room. To check for artifact and secure electrode attachment, the subject was asked to "make a fist with both hands, raise your arms off the chair, and shake them a little" and then to "close your eyes and shake your head a bit". (This procedure also permitted a test of whether the EMG and MVT channels were operating properly). Electrodes were adjusted or reapplied if necessary. When recordings were satisfactory, the lights in the experimental chamber were dimmed and the door was closed.

At this point the subject was randomly assigned to a condition in which he would receive either training for increases in heart rate (INC), decreases in heart rate (DEC) or both (INC/DEC). Tape recorded instructions were played over the intercom (Appendix B). Instructions for the INC and DEC groups informed the subject he would receive a series of trials in which his task would be to move the feedback dash as far as possible in the direction of the letter A located at the top of the screen. A simulated feedback display was provided to illustrate this. He was also informed that following training he would receive a set of transfer trials in which he would be required to produce the response without the aid of feedback. A sample transfer display containing just the letter A was presented. Subjects in the INC/DEC group were similarly instructed but were also informed they would receive training on a second response, designated by the letter B. Simulated training and transfer displays with the letter B accompanied this instruction. Finally, all subjects were advised to use any method they wished to produce the response(s) as long as they did not "touch or put pressure upon the electrodes". Subjects were also told that successful performance would be rewarded with bonus money up to a possible total of $2.00.

Each trial consisted of a thirty-second pretrial period during which baseline responding was recorded but no visual display was present. A thirty-second trial period then followed and was designated by presentation of the feedback display (Figure 1). "Change scores" were calculated for each response by subtracting the pretrial mean from trial means, except in the case of respiratory amplitude and volume where trial means for these variables were divided by the corresponding pretrial means. Cardiac IBIs were averaged during pretrial and trial periods and converted to heart rate to obtain heart-rate change scores. Feedback was proportional to the difference between the most recent IBI and the last IBI recorded during the pretrial period.

Because decreases in heart rate are more difficult to produce than increases (Yates, 1980), the sensitivity of the feedback display during decrease trials was twice that of increase trials so that obtained excursions of the dash toward the top of the screen were comparable. A 60 msec shortening of the IBI from the pretrial period produced an upward excursion of the feedback dash of 2 cm on increase trials; a 30 msec lengthening of the IBI from the pretrial referent produced an upward excursion of 2 cm on decrease trials. Roberts et al. (1984) found that this procedure equated the perceived difficulty of heart-rate increase and decrease trials.

For the INC and DEC groups training involved the initial presentation of 4 transfer trials, 12 feedback trials, followed again by 3 transfer trials. Transfer trials were identical to feedback trials except for the presence of feedback. Four "blank trials" on which no feedback or trial cues appeared but physiological recordings were still taken, were randomly interspersed in training and two were interspersed in the second transfer block. This made a total of 25 trials for the INC and DEC groups. The INC/DEC group received a mixed series of 4 transfer trials (2 increase and 2 decrease) followed by a mixed series of 12 training trials (6 increase and 6 decrease) followed by 6 transfer trials (3 increase and 3 decrease). Four blank trials were randomly interspersed in training and three in transfer. This made a total of 29 trials in the INC/DEC group. The entire session took approximately seventy-five minutes.

Post-training reports

When the session was completed the subject was taken from the experimental chamber, the electrodes were removed and two written questionnaires were administered (Appendix C). The first recorded an open ended reply to the question: "Describe what you did to make the dash move in the direction of the A on A-trials". Subjects in the INC/DEC group had an additional question that asked them to describe what they did on B-trials. When this first questionnaire was completed, it was collected and a second questionnaire was presented. The second questionnaire asked the subject to rate on seven-point scales (1 = not at all; 7 = a great deal) the extent to which he employed the following activities on A-trials (B-trials as well for two-target subjects): tensed muscles; relaxed muscles; slow breathing; rapid breathing; moved around in the chair; kept very still; calming thoughts; anxious thoughts; exciting thoughts; and blank mind. In addition, to ensure that the subjective difficulty of increases and decreases were comparable, all subjects were asked to rate on a separate seven-point scale their degree of perceived success. The rating scales are reproduced in Appendix C. Upon completion of these questionnaires the subject was debriefed and released.

Ten judges were recruited from graduate students and faculty in the Psychology Department at McMaster. These judges, blind to target condition, were given transcribed copies of the open-ended reports for all three groups and instructions on how to sort them (Appendix D). These instructions asked judges to decide, for the one-response groups, whether the report was from a subject trained to increase or decrease his heart rate. For the two-response group a decision was to be made whether the subject increased his heart rate on A-trials and decreased it on B-trials, or the reverse. Judges were also asked to state the confidence of their judgements and the reasons for their decisions. Judges acted independently of one another but were given some guidelines to assist their task. They were told that reference to increased somatomotor or respiratory activity probably meant an increase in heart rate had been required, and that a decrease in these activities probably indicated decreases in heart rate. These decision rules were based upon prior evidence concerning heart-rate correlates (Obrist, Galosy, Lawler, Gaebelein, Howard & Shanks, 1975; Obrist, 1981) and not upon the subjects' measured response patterns. Measurement of these patterns, however, provided a partial check upon whether these rules were correct.

Data Reduction

Seven subjects were eliminated from the analysis because of equipment failure (n = 1), excessive artifact in their physiological recordings (n = 4), or a combination of these problems (n = 2). Five of these subjects were in the INC/DEC group and one in each of the single-response groups. For the remaining 48 subjects, response concomitants and/or trials were eliminated if the recordings contained artifact or indicated improper functioning. In this manner electromyographic activity was rejected for two subjects, skin conductance for seven subjects and respiration for two subjects. Less than 1% of all remaining trials were eliminated because of artifact.

Data analysis

Heart-rate changes in the INC and DEC groups were analyzed by a 2x12 analysis of variance (ANOVA) applied to feedback trials. The variates were target condition (increase or decrease heart rate, a between-subjects variable) and trial number (12, a within-subjects variable). A separate 2x6 ANOVA was applied to feedback trials for the INC/DEC group. Heart-rate target (increase or decrease) and trial number were the within-subject variates. Comparisons between the single target and two-target groups were made with two-tailed t-tests. Transfer was analyzed separately by ANOVAs patterned after those applied to feedback trials.

To confirm that cardiac changes were accompanied by somatomotor and/or respiratory changes, Pearson product-moment correlations between changes in heart rate and changes in electromyographic activity, movement, respiration frequency and respiration volume over the course of the session were calculated for subjects in the INC/DEC group. Respiration amplitude is not reported because of its very high correlation with respiration volume. Skin conductance is not reported because it is not relevant to the issues addressed in this thesis.

Evidence for response awareness in the open-ended reports was sought by determining whether the judges could assign the reports to correct training condition at a level exceeding chance. This was done for the single-target groups by a two-sample, one-tailed Kolmogorov-Smirnov test, and for the INC/DEC group by a one-sample, one-tailed Kolmogorov-Smirnov test. Evidence for response awareness in the rating scales was sought by determining whether the ratings differed significantly between trial types. For this purpose a two-sample, one-tailed Kolmogorov-Smirnov test was applied to the single-target groups, and a one-tailed Wilcoxon test to the two-target group. In addition, a composite score of the scale ratings was calculated by summing ratings given for increase compatible activities (increased muscle tension, rapid breathing, movement, anxious thoughts, exciting thoughts) and subtracting ratings given for decrease compatible activities (relaxed muscles, slow breathing, keeping still, calming thoughts). The composite scores were also compared across training conditions. Two-sample Kolmogorov-Smirnov tests were used to determine whether assignment of the open-ended reports or ratings on the scales differed between the single and two-response groups.

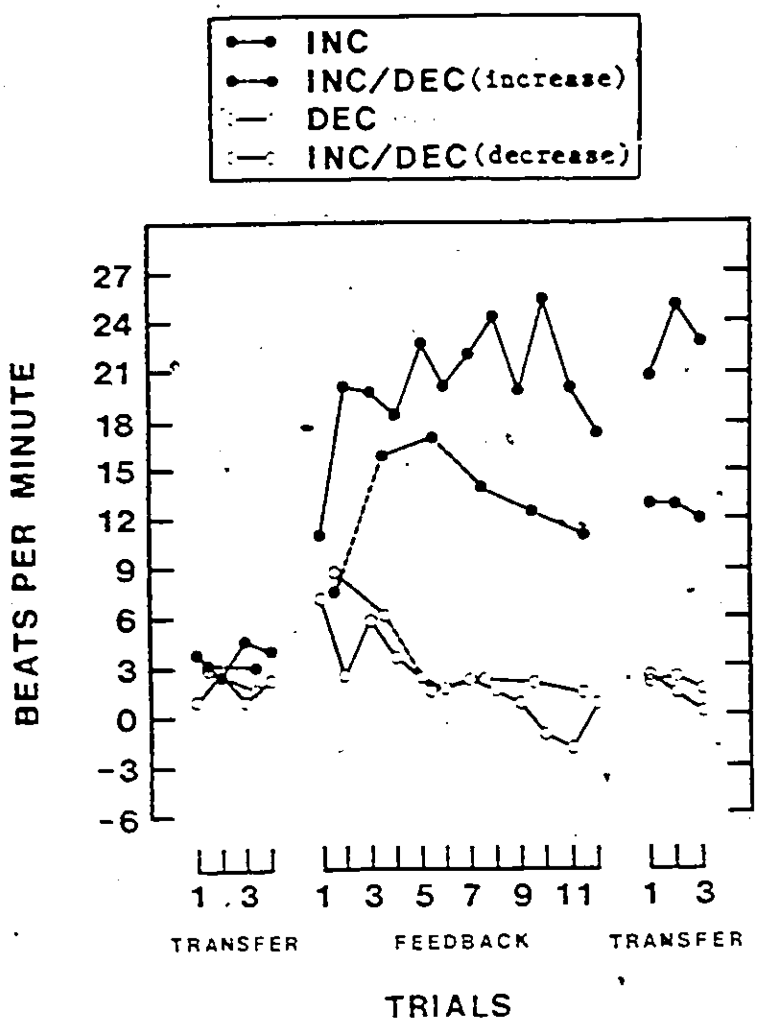
RESULTS

Heart-rate control

Control of heart rate during feedback training and transfer is shown for all three groups in Figure 2. Each data point represents heart-rate changes from the pretrial baseline. As expected, control of the response was not evident during the transfer block administered prior to feedback training. Analysis of variance for the INC and DEC groups in feedback training revealed an effect of target, $F(1,22) = 13.72$, $p<.05$, and an interaction between target and trial number, $F(11,242) = 2.19$, $p<.05$. This indicates that the average heart rate of the INC group (20.0 bpm) was significantly higher than that of the DEC group (2.0 bpm) and that group differentiation improved with training. Significant group differentiation was again obtained in the transfer block following training, $F(1,22) = 18.48$, $p<.05$, although in this case there was no improvement over trials. Average heart-rate change was 22.9 bpm in the INC group and 2.2 bpm in the DEC group. A separate ANOVA for the INC/DEC group in training also revealed a main effect of target, $F(1,23) = 13.62$, $p<.05$, and an interaction between target and trial number, $F(5,115) = 6.02$, $p<.05$, indicating that response differentiation had occurred and improved with training. The average increase was 12.9 bpm and the average decrease was 3.2 bpm. Similarly, differentiation was evident in the transfer block following training, $F(1,23) = 11.35$, $p<.05$, but did not improve over trials. Average increase performance was 12.4 bpm and average decrease performance was 1.4 bpm.

Inspection of Figure 2 reveals that subjects trained to produce

Figure 2. Heart-rate changes from pretrial baseline during feedback training and transfer in Experiment 1. Increase trials are represented by solid circles and decrease trials are represented by open circles. The single-target groups are represented by solid lines and the two-target group is represented by broken lines.



INC
INC/DEC(increase)
DEC
INC/DEC(decrease)
BEATS PER MINUTE
27
24
21
18
15
12
9
6
3
0
-3
-6
1 3
1 3 5 7 9 11
1 3
TRANSFER
FEEDBACK
TRANSFER
TRIALS

Figure 2

increases in heart rate were successful, but decrease training was generally unsuccessful. This latter result was confirmed by _t_-tests that found no significant difference between decrease trial performance and blank trial performance in either training or transfer for either the DEC or the INC/DEC group. Despite this result, a Kolmogorov-Smirnov test applied to ratings of target difficulty did not differ significantly between the INC and DEC group ($\underline{M}_{INC} = 3.8$; $\underline{M}_{DEC} = 3.1$). Similarly, a Wilcoxon test found no significant differences in reported difficulty between the increase and decrease conditions within the INC/DEC group ($\underline{M}_{inc} = 3.5$; $\underline{M}_{dec} = 2.4$) (i.e. 1 = not very successful; 7 = very successful).

Comparisons of the magnitude of heart-rate control found in the single versus two target groups in training and transfer were made using two-tailed _t_-tests. All comparisons proved nonsignificant.

Concomitant Responses

Table 2 lists within-subject product-moment correlations between heart-rate changes and changes in electromyographic activity, gross body movement, respiration frequency and respiration volume over the course of the session for subjects in the INC/DEC group. The left-hand side of the table lists correlations for subjects who achieved significant heart-rate differentiation in training and the right-hand side of the table lists correlations for subjects who failed to achieve significant training differentiation. The underlined values indicate concomitants that had significant trial-type differentiation during transfer as measured by a two independent sample _t_-test (one-tailed) that compared changes on increase transfer trials to decrease transfer trials.

Table 2: Within-subject correlations between heart-rate changes and changes in concomitant responses in Experiment 1

DIFFERENTIATORS

Subject	EMG[a]	MVT[b]	RF[c]	RV[d]
INC/DEC-10	.73*	.80*	-.01	.64*
INC/DEC-15	.83*	.90*	-.73*	.48*
INC/DEC-20	.32	.72*	-.17	.67*
INC/DEC-23	.32	.14	-.38*	.01
INC/DEC-26	.89*	.31*	-.10	.68*
INC/DEC-29	.79*	.48*	.04	.82*
INC/DEC-31	.85*	.82*	-.45*	.65*
INC/DEC-37	.90*	.78*	-.50*	.56*
INC/DEC-39	.20	.68*	-.13	.67*
INC/DEC-55	-.11	.69*	-.58*	.36*
M[f] =	.67*	.68*	-.31	.58*

NONDIFFERENTIATORS

Subject	EMG	MVT	RF	RV
INC/DEC-2	.15	.36*	-.17	.47*
INC/DEC-8	.51*	.58*	-.50*	.54*
INC/DEC-9	.48*	.19	-.12	.35*
INC/DEC-11	.04	-.35*	.03	-.52*
INC/DEC-13	na[e]	.40*	.17	.51*
INC/DEC-16	.78*	.55*	-.42*	.64*
INC/DEC-19	.63*	.34*	-.10	.40*
INC/DEC-35	.43*	.84*	-.05	.63*
INC/DEC-41	.68*	.54*	-.19	.01
INC/DEC-44	.45*	.62*	-.33*	.62*
INC/DEC-45	.67*	.73*	-.61*	.67*
INC/DEC-47	.53*	.65*	-.28	.66*
INC/DEC-50	.18	.61*	-.26	.54*
INC/DEC-56	.28	.39*	-.44*	.43*
M[f] =	.48*	.51*	-.25	.46*

Note. Underlined values indicate significant differentiation of this concomitant between increase and decrease transfer trials as measured by a one-tailed *t*-test.

[a] Forearm electromyogram [b] Body movement [c] Respiratory frequency
[d] Respiratory volume [e] Not available [f] *r* to *z* transformed

* $p < .05$

Table 2 makes two points. The first is that there is a significant association between changes in heart rate and concomitant changes in somatomotor and respiratory activities as indicated by the mean correlation coefficients at the bottom. Furthermore, inspection of individual performance indicates that there is no individual in this experiment who achieved significant heart-rate control without accompanying changes in one or more of the above concomitants. Significant differentiation of the concomitants between increase and decrease trials occurred in many cases. (Because heart rate is influenced by many different response systems, heart-rate differentiation can, and often will occur in the absence of any one concomitant (Obrist, 1981)). The second point made by Table 2 is that the response organization of subjects who achieved significant heart-rate control was not significantly different from the response organization of those who failed to achieve control. Significant associations with somatomotor and respiratory activities existed for both controllers and noncontrollers, but this relationship was utilized to achieve heart-rate control only in the former group.

Post-training reports

Kolmogorov-Smirnov tests were used to assess response awareness in the open-ended verbal reports. In the INC/DEC group, a one sample, one-tailed Kolmogorov-Smirnov test was applied to determine whether the distribution of the proportion of subjects correctly assigned by each judge differed from the distribution that would be expected on the basis of chance. This procedure indicated that the obtained distribution differed from chance, $\underline{D}(10) = 9.9$, $\underline{p} < .05$. The average judge assigned

19.7/24 reports correctly, compared to a chance expectation of 12/24 reports.

For the single-target groups, a comparison was made between the distribution of the proportion of judges who assigned each open-ended report to the increase training condition within the INC group as compared to the DEC group. A two-sample, one-tailed Kolmogorov-Smirnov test showed that these distributions differed between the INC and DEC groups, $\underline{D}(12) = 8$, $\underline{p} < .05$. The average proportion of judges assigning reports to the increase training condition within the INC group was .84 (i.e 8.4/10 judges), and .27 within the DEC group.

Statistical comparisons between the scale ratings were also undertaken. One-tailed Wilcoxon tests for the INC/DEC group revealed differences between increase and decrease trials for the following reported activities: tensed muscles ($\underline{T}(22) = 52.5$, $\underline{p} < .05$), relaxed muscles ($\underline{T}(21) = 42.5$, $\underline{p} < .05$), calming thoughts ($\underline{T}(21) = 34$, $\underline{p} < .05$), anxious thoughts ($\underline{T}(20) = 50$, $\underline{p} < .05$) and exciting thoughts ($\underline{T}(19) = 34.5$, $\underline{p} < .05$). Composite scores for each subject that summed ratings for relevant increase activities (tensed muscles, rapid breathing, movement, exciting thoughts and anxious thoughts) and subtracted ratings for decrease activities (relaxed muscles, slow breathing, kept still, calming thoughts) proved to be significantly different across trial type, $\underline{T}(24) = 63.5$, $\underline{p} < .05$.

A two sample, one-tailed Kolmogorov-Smirnov test was applied to the scale ratings given by the single-target groups. Subjects rated tensing of the muscles more highly in the INC group, ($\underline{D}(12) = 9$, $\underline{p} < .05$), and relaxing of the muscles more highly in the DEC group ($\underline{D}(12) = 6$,

$p < .05$). However, ratings on the other individual scales were not different. As was found in the INC/DEC group, the composite score differentiated between trial types, $D(12) = 6$, $p < .05$.

Finally, comparisons were made between the one and two-response groups. Kolmogorov-Smirnov tests found no significant differences between proportion of correct assignment or between ratings on the individual or composite rating scales.

Relationship between control and self-report

A final group of analyses examined the relationship between the magnitude of learning and the veridicality of self-report. Because learning on an individual basis can be inferred only with bidirectional performance, these analyses were restricted to the INC/DEC group.

With the open-ended reports, the proportion of judges that correctly assigned an individual's report to training condition was found to be significantly correlated with magnitude of control, *rho* = .59, $p < .05$. Correlations with the quantitative scale ratings revealed significant relationships in the appropriate direction for tensed muscles (*rho* = .44, $p < .05$), relaxed muscles (*rho* = .43, $p < .05$), rapid breathing (*rho* = .39, $p < .05$), anxious thoughts (*rho* = .42, $p < .05$) and exciting thoughts (*rho* = .32, $p < .05$). The correlation with the composite scores was also significant, *rho* = .66, $p < .05$.[3]

Although the general pattern of results indicates strong relationships between self-report and control, it is possible that there are individual subjects who gave evidence of learning without having accurate self-report. A final analysis attempted to determine if there was any evidence of this. Subjects were classified as differentiators or nondifferentiators on the basis of a two independent sample *t*-test (one-tailed) that compared each subject's increase performance on feedback trials against his decrease performance on feedback trials. Subjects were further divided into those showing evidence of accurate self-report and those not showing evidence of such report, on the basis of whether at least nine out of the ten judges correctly assigned the subject's report to training condition. Of the ten subjects with significant bidirectional training, all had their reports correctly assigned to training condition by a minimum of 9 out of 10 judges on the sorting task, and all subjects had positive composite scores.

A summary of the performance of all individuals is contained in Table 3.

DISCUSSION

The main finding of this experiment is that significant heart-rate differentiation between the group trained to increase heart rate and the group trained to decrease heart rate was accompanied by reports of activities used to produce the response that were also significantly different. Hence, the relationship between accurate self-report and visceral control that was reported by Roberts et al. (1984) is not dependent on the bidirectional training procedure that was used in that research. All comparisons between the single and two-response groups proved nonsignificant in the present study, indicating that this variable probably cannot account for the discrepancy of the Roberts et al. (1984) findings and the early studies that reported learning without awareness.

Table 3: Summary of individual performance in Experiment 1

DIFFERENTIATORS

Subject	Training bpm[a]	Transfer bpm[a]	PCA[b]	COMP[c]
INC/DEC-10	30.9*	25.6*	1.0	45
INC/DEC-15	31.0*	32.6*	1.0	52
INC/DEC-20	6.8*	10.2*	.9	47
INC/DEC-23	11.2*	10.1	1.0	8
INC/DEC-26	29.2*	2.5	1.0	30
INC/DEC-29	29.0*	39.3*	1.0	39
INC/DEC-31	36.5*	48.6*	1.0	32
INC/DEC-37	28.0*	45.7*	1.0	39
INC/DEC-39	13.7*	10.8	.9	46
INC/DEC-55	10.6*	.8	1.0	44

NONDIFFERENTIATORS

Subject	Training bpm	Transfer bpm	PCA	COMP
INC/DEC-2	-2.4	.8	.9	5
INC/DEC-8	1.0	10.1*	.6	10
INC/DEC-9	-.7	7.3	.8	2
INC/DEC-11	2.5	4.9	.8	-3
INC/DEC-13	-1.9	.1	.4	-47
INC/DEC-16	-3.9	7.3	1.0	1
INC/DEC-19	8.4	6.2	1.0	42
INC/DEC-35	9.7	12.7*	.3	-34
INC/DEC-41	.1	-.2	.9	10
INC/DEC-44	.6	13.6*	1.0	24
INC/DEC-45	4.8	10.1*	.6	2
INC/DEC-47	-4.0	-3.1	.2	-21
INC/DEC-50	.5	-1.7	.8	37
INC/DEC-56	-2.0	-12.2	.6	-2

[a] Average bidirectional (increase minus decrease) change in beats per minute during training and transfer. Significance determined by a *t*-test (one-tailed) that compared increase performance versus decrease performance.

[b] Proportion of judges correctly assigning an individual's open-ended report to training condition.

[c] Composite score from the rating scales. Ratings on all the relevant increase activities are subtracted from ratings on all the relevant decrease activities. Positive values indicate an overall rating in the appropriate direction.

* $p < .05$

Experiment 1 also replicated the results of Roberts et al. (1984) with regard to response awareness during bidirectional heart-rate training. In the INC/DEC group, a significant correlation between bidirectional control on feedback trials and assignment of the verbal reports by the judges indicated that subjects with the largest bidirectional heart-rate changes in the direction of training were more likely to report veridical information than subjects with smaller or inappropriate heart-rate changes. Feedback differentiation without correct assignment of the reports to training condition by at least 9 of 10 judges was not observed in this study or in Experiment 1 of Roberts et al. (1984) in which the same procedure was used.

Although there were no subjects with significant bidirectional training without consistent assignment of their reports in the present study, there were three subjects who achieved significant bidirectional transfer without having their reports consistently assigned (INC/DEC-8; INC/DEC-35; INC/DEC-45). Because a determination of whether awareness is present on an individual basis is not possible, these cases may be best interpreted in their overall context. Including the present experiment there have now been 100 subjects trained with the bidirectional heart-rate procedure in this laboratory (Roberts et al., 1984, Experiments 1 & 4; Hughes & Roberts, 1985, Groups C & E). Fifty-two of these 100 subjects failed to differentiate on training trials. If transfer were a random occurrence among these subjects, significant transfer would be expected in two or three instances at a probability level of .05. There are actually six times this many (18 in all), so it would appear that some learning has occurred. However, in 16 of these

18 cases, proportion of correct assignment also exceeded a chance level (mean Proportion of Correct Assignment (PCA) = .82, $p<.01$, sign test), indicating the presence of accurate knowledge as well.

Of final note is the fact that even though differentiators of the present study showed consistent assignment of their verbal reports, a number of nondifferentiators did so as well (e.g. INC/DEC-2; INC/DEC-16; INC/DEC-19; INC/DEC-41). Thus, even though reportable information about the response bears a strong association to control of the response, it does not ensure control of the response.

CHAPTER 4: EXPERIMENT 2

The purpose of Experiment 2 was to assess the effect of forewarning of transfer on response awareness and control. Forewarning of transfer was employed in Experiment 1 of this thesis and in Roberts et al. (1984) but was an uncommon procedure in earlier studies purporting to show learning without awareness (see Table 1). It is conceivable that forewarning subjects the response will eventually have to be produced without feedback may cause them to encode response information in a manner that allows retrieval when feedback is not available to serve as a memory aid. Self-report, as well as control (especially in transfer) may benefit from this orientation and may have been partly responsible for the results obtained in Experiment 1.

Some evidence of this type of effect has been demonstrated in other literatures. Rommetveit (1960; 1965) found that subjects forewarned that they would eventually have to provide a verbal report of their actions learned a concept faster than a group not forewarned of this requirement. Bransford, Franks, Morris & Stein (1979) and Tulving (1979) have demonstrated that various types of cognitive learning tasks transfer best to a test situation when they are processed in a manner compatible with the demands of the testing situation.

Specifically, then, the present experiment retained single target heart-rate training to make comparisons with the early studies more direct. There were four groups altogether. Two groups were trained to produce heart-rate increases (INC) and two groups were trained to produce heart-rate decreases (DEC). One of each of these groups was forewarned of transfer (FW) and the other one was not forewarned (NFW). The four conditions were therefore designated INC-FW, INC-NFW, DEC-FW and DEC-NFW.

Another change from Experiment 1 was the addition of a second transfer test that, in addition to trials on which subjects were to produce the response without feedback, included trials on which the subject was to "make the response go the opposite way". The purpose of "Transfer 2" was to obtain a bidirectional measure of control that might be taken to indicate response learning on an individual basis. For INC subjects it should be noted that bidirectional differentiation during Transfer 2 is not unambiguous as a measure of learning because appropriate heart-rate differentiation may be elicited by the task orientation rather than as a result of extended experience with the feedback. This is due to the fact that subjects are required to move the dash upwards on one trial type (i.e. which may prompt increases in behaviour) and asked to make the response go in the opposite direction on the other trial type (i.e. which may prompt behavioural decreases). However, success at bidirectional control during Transfer 2 can be taken as evidence for response learning for subjects in the DEC groups. This is because changes in heart rate elicited by task instructions can be expected to subtract from changes due to learning in these groups.

METHOD

The method is the same as used in Experiment 1 except for the following differences.[4]

Subjects

Forty-four male volunteers from the McMaster University community and local high schools, aged 15 to 48 (M = 20.5), received $2.00 per hour for their participation. Eleven subjects were in each of the four groups.

Apparatus and Electrophysiological Recording

A PDP-8/L computer controlled trial sequencing, data recording, and the feedback display. Heart rate and respiration were sampled via an A/D converter at 125 msec intervals and skin conductance at 250 msec intervals as in Experiment 1, but electromyographic activity and movement were sampled at 250 msec intervals. On the basis of these data, five second averages were calculated by the PDP-8/L for each measure during both the pretrial and trial periods.

Heart rate was recorded in the following way. The raw electrocardiogram was post-amplified and fed to a digital circuit which discriminated the R-wave from muscle and movement artifact. The output of this circuit triggered a cardiotachometer (Beckman 9857B) with a continuous analog output of 30 bpm/v. This output was used by the computer to drive the feedback display generated by a Tetronix 4501 scan converter and a Computec C118 display interface. Feedback was given for heart-rate changes from the last five second pretrial average and updated every 125 msec. The display appeared on a Sony videomonitor (Model 110) with a screen size of 18 cm x 23 cm.

Electromyographic signals were rectified and integrated by a Beckman 9873B coupler (2 mv/cm; IC = 1; TMW = 3.0). Integrator resets were counted via digital input buffers on the PDP-8/L. Movement was recorded in the same manner with the sensitivity of the coupler set to 50 mv/cm.

Procedure

Following the medical interview and electrode attachment, subjects were randomly assigned to one of the four experimental conditions (INC-FW, INC-NFW, DEC-FW, DEC-NFW).

Tape recorded instructions (Appendix E) informed the subject that he would be trained on a set of discrete trials in which his task was to move the feedback dash as far as possible in the direction of the letter A at the top of the screen. A sample feedback display was provided (Figure 1). Subjects in the FW condition were further told that they would be asked to produce the target response without feedback when training was finished. A sample display containing only the letter A was provided to illustrate transfer trials. It was explained that although transfer trials would not be given until the end of training, we wanted subjects to know now that production of the response without feedback would later be required. Reference to the transfer requirement was omitted altogether for subjects in the NFW condition. Finally, all subjects were advised that successful performance would be rewarded with bonus money up to a possible total of $1.00.

Training consisted of ten feedback trials and two blank trials, one given at the end of training and the other randomly interspersed amongst the feedback trials. The initial transfer block was omitted for all groups.

Upon completion of training the experimenter reentered the experimental chamber to administer the first questionnaire (Verbal

Report 1) (Appendix F). This questionnaire asked subjects to describe what they had done to "move the dash in the direction of the letter A" and to rate their degree of perceived success. Subjects remained in the chair with the electrodes attached while filling out this report. Upon completion, the lights were dimmed in anticipation of the resumption of testing.

At this point tape recorded instructions indicated to subjects in all groups that production of the response without feedback would now be required. A sample display containing the letter A alone was given to illustrate transfer trials. This phase in the experiment, designated herein as Transfer 1, consisted of three transfer trials and two blank trials given in a mixed sequence.

A second transfer test (referred to herein as Transfer 2) was given following Transfer 1. Tape recorded instructions informed the subjects that, in addition to further transfer trials designated by the letter A, trials designated by the letter B would also appear. On B-trials their task was to "try to make the response go the opposite way......even though the feedback dash will not be available to tell you how successful you have been". Transfer 2 consisted of three A, three B, and two blank trials given in a mixed order.

Two questionnaires administered after Transfer 2 completed the experiment. The first asked subjects to describe in writing what they had done to "produce the response on A-trials" and what he had done "on B-trials to make the response go in the opposite direction" (Verbal Report 2) (Appendix F). The second asked subjects to rate, by means of quantitative scales, the extent to which he used certain activities (same as used in Experiment 1).

Post-training reports

Ten judges were given 44 sheets of paper containing transcribed copies of Verbal Report 1 and Verbal Report 2 and instructions on how to sort them (Appendix G). These instructions asked the judges to make a decision as to whether the subject increased his heart rate on A-trials and decreased it on B-trials, or the reverse. Guidelines for making these decisions were the same as in the previous experiment.

Data Reduction

Eleven subjects were eliminated from the analysis because of equipment failure (n = 5), procedural inconsistencies (n = 2), excessive artifact in their physiological recordings (n = 2), or a combination of these problems (n = 2). Four were in the INC-FW group, one in the INC-NFW group, two in the DEC-FW group, and four in the DEC-NFW group. For the remaining 44 subjects, electromyographic activity was rejected for two subjects and skin conductance for two subjects. Technical complications did not allow for the analysis of any of the respiration data. Fewer than 1% of all remaining trials were eliminated because of artifact. Relationships between heart rate and the concomitant responses were examined and found to be similar to that obtained in Experiment 1. For ease of presentation, these data are contained in Appendix I and will not be described further. Group heart-rate changes in Transfer 2 are contained in Appendix H for similar reasons.

RESULTS

Heart-rate control

Control of heart rate in beats per minute on feedback trials and during Transfer 1 is shown for each group in Figure 3. Analysis of variance revealed a significant overall effect of target condition (INC vs. DEC) in training, $F(1,40) = 11.1$, $p<.05$, as well as during Transfer 1, $F(1,40) = 10.5$, $p<.05$. Average heart-rate change in training was 7.6 bpm for INC and .1 bpm for DEC. Average heart-rate change in Transfer 1 was 11.8 bpm for INC and .5 bpm for DEC. No interaction between target condition and trial number was obtained in either training or Transfer 1, indicating that heart-rate changes on the initial trial did not differ significantly from subsequent trials. Increase performance was significantly greater than blank trial performance in both training and Transfer 1 but decrease performance was not different in either. No effect of forewarning was found in training or in Transfer 1.

Despite the greater ease with which subjects were able to produce increases in heart rate over decreases, a Kolmogorov-Smirnov test determined that ratings of perceived success did not differ significantly between the INC and DEC group within either the FW or NFW conditions ($M_{INC-FW} = 4.4$; $M_{INC-NFW} = 4.3$; $M_{DEC-FW} = 4.9$; $M_{DEC-NFW} = 4.6$).

Post-training reports

The contents of the open-ended reports were analysed by means of Kolmogorov-Smirnov tests that examined the distribution of the proportion of judges who assigned each open-ended report to increase

Figure 3. Heart-rate changes from pretrial baseline during feedback training and Transfer 1 in Experiment 2. Increase trials are represented by solid lines and decrease trials are represented by broken lines. The Forewarned groups are represented by solid circles and the Not-Forewarned groups are represented by open circles.

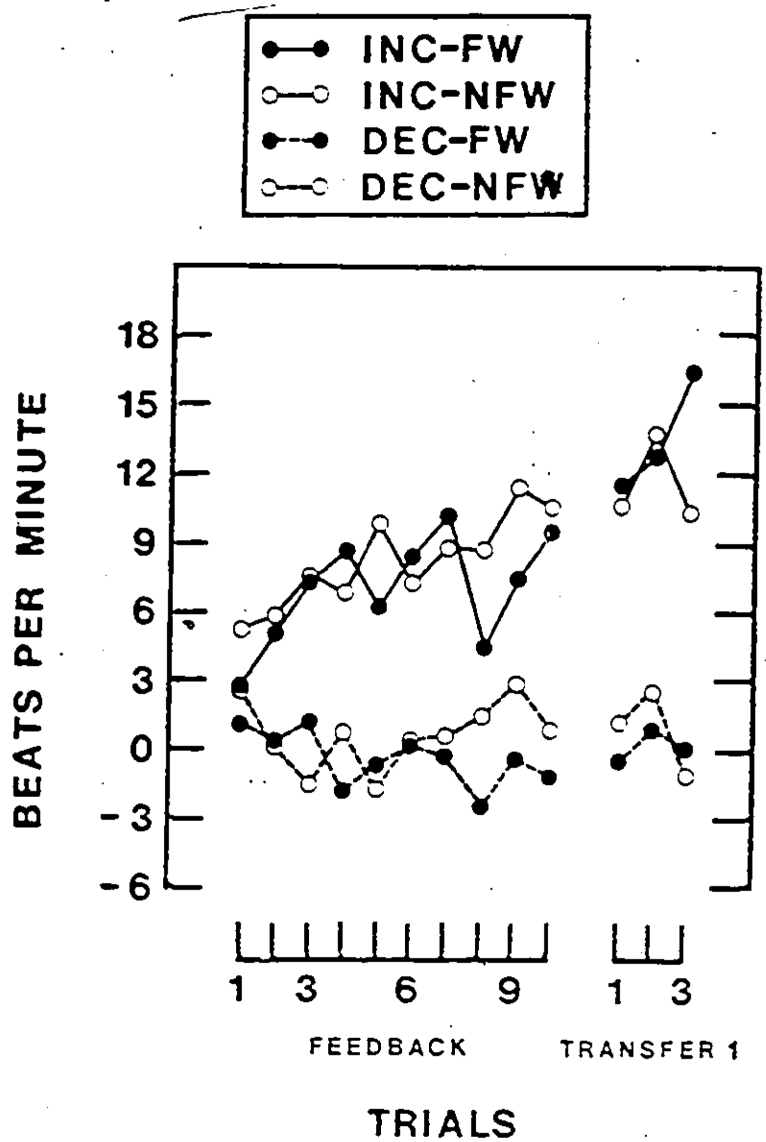

INC-FW
INC-NFW
DEC-FW
DEC-NFW
BEATS PER MINUTE
18
15
12
9
6
3
0
-3
-6
1
3
6
9
1
3
FEEDBACK
TRANSFER 1
TRIALS

Figure 3

training in the INC versus the DEC groups. This was done separately for the FW and NFW conditions. Within the FW condition, the open-ended reports of INC subjects were assigned significantly more frequently to increase training than were the reports of DEC subjects, $D(11) = 5$, $p<.05$. Within the NFW condition the same result was obtained, $D(11) = 6$, $p<.05$. This same result was also obtained when the FW and NFW conditions were combined, $D(22) = 8$, $p<.05$. The average proportion of judges assigning an individual report to the increase training condition for each group was as follows: INC-FW = .70 (i.e. 7/10 judges); DEC-FW = .47; INC-NFW = .80; DEC-NFW = .40.

The same statistical procedure was applied to the scale ratings. Within the FW condition the reported use of the following activities differentiated between the INC and DEC group: tensed muscles ($D(11) = 7$, $p<.05$), relaxed muscles ($D(11) = 5$, $p<.05$), slow breathing ($D(11) = 6$, $p<.05$), rapid breathing ($D(11) = 6$, $p<.05$) and calming thoughts ($D(11) = 7$, $p<.05$). The composite scale also differentiated between the INC and DEC groups, $D(11) = 6$, $p<.05$. This statistical procedure applied to the NFW condition found the reported use of the following activities to be significantly different between the INC and DEC groups: tensed muscles ($D(11) = 6$, $p<.05$), relaxed muscles ($D(11) = 7$, $p<.05$), slow breathing ($D(11) = 6$, $p<.05$), rapid breathing ($D(11) = 6$, $p<.05$), movement ($D(11) = 5$, $p<.05$), kept still ($D(11) = 5$, $p<.05$), calming thoughts ($D(11) = 6$, $p<.05$), anxious thoughts ($D(11) = 7$, $p<.05$) and exciting thoughts ($D(11) = 5$, $p<.05$). The composite scale was also significant, $D(11) = 7$, $p<.05$.

A possible effect of forewarning on accurate self-report was assessed by determining whether correct identification on the sorting task or ratings on the scales differed between the FW and NFW groups within each target condition. No differences attributable to this variable were found.

Relationship between control and self-report

Correlations between self-report and bidirectional heart rate in Transfer 2 were calculated to determine if there was any relationship between the veridicality of the information reported and control of the response. Proportion of correct assignment in the open-ended reports was found to be significantly correlated with magnitude of control in three of the four groups: INC-FW, *rho* = .89, $p<.05$; DEC-FW, *rho* = .85, $p<.05$; DEC-NFW, *rho* = .66, $p<.05$. Only in the INC-NFW group did this relationship fail to achieve significance, *rho* = .49, $p>.05$.

Scores on the rating scales were correlated with bidirectional control in Transfer 2. For the INC-FW group, scores on all of the individual scales were significantly correlated in the appropriate direction, as was the composite score, *rho* = .91, $p<.05$. Similarly, all scales were significantly related in the expected direction for both the DEC-FW (composite: *rho* = .85, $p<.05$) and the DEC-NFW group (composite: *rho* = .89, $p<.05$). On the other hand, none of the scales were significantly related to heart-rate control in the INC-NFW group and a few were in the wrong direction (composite: *rho* = .17, $p>.05$).

All comparisons between the correlation coefficients proved to be nonsignificant.

A final analysis attempted to determine if there was any evidence of individual subjects having controlled the response without showing accurate self-report. Subjects were divided into differentiators and nondifferentiators on the basis of a one-tailed *t*-test that compared each subject's increase performance with his decrease performance in Transfer 2. and into those showing evidence of accurate self-report and those not on the basis of whether at least nine out of ten judges assigned the report to correct training condition. Of the sixteen subjects who controlled the response, all but three had their open-ended report consistently assigned to training condition (INC-NFW-28; INC-NFW-41; DEC-NFW-33).[5] However, none of these cases provides unambiguous evidence of learning without awareness. Because two of these subjects were in the INC condition, an elicited basis for bidirectional control cannot be ruled out. Subjects INC-NFW-28 and DEC-NFW-33 did not have significant control of heart rate during training. Finally, all three had high positive composite scores suggesting at least recognition of veridical strategies.

A summary of the performance of all individuals in Experiment 2 is contained in Table 4.

DISCUSSION

The results of this experiment demonstrate that accurate self-report is not dependent upon forewarning subjects of transfer and that this variable is not likely responsible for the discrepancy between recent studies of response awareness in biofeedback (Roberts et al., 1984) and the early studies that reported learning without awareness. Within the NFW condition, significant heart-rate differentiation between the group trained to increase heart rate and the group trained to

Table 4: Summary of individual performance in Experiment 2

DIFFERENTIATORS

Subject	Training bpm[a]	bidirec. Transfer bpm[b]	PCA[c]	COMP[d]
INC-FW-16	18.6*	45.3*	1.0	49
INC-FW-17	38.9*	64.0*	1.0	44
INC-FW-24	3.6*	20.5*	1.0	33
INC-FW-31	.9	6.6*	1.0	43
INC-FW-32	4.1	16.6*	1.0	32
INC-FW-36	8.9*	31.8*	1.0	42
INC-NFW-7	7.4*	19.4*	1.0	44
INC-NFW-20	12.3*	16.0*	.9	14
INC-NFW-27	1.5	21.4*	1.0	29
INC-NFW-28	1.4	3.8*	.2	9
INC-NFW-41	20.1*	38.6*	.8	28
DEC-FW-4	-2.8	32.5*	1.0	50
DEC-FW-40	-4.0*	14.2*	1.0	31
DEC-NFW-22	1.5	16.2*	.6	34
DEC-NFW-42	-2.9	27.3*	1.0	46
DEC-NFW-43	-3.0	26.0*	.9	40

NONDIFFERENTIATORS

Subject	Training bpm	bidirec. Transfer bpm	PCA	COMP
INC-FW-1	-1.8	-2.8	.3	0
INC-FW-21	2.6	4.0	.4	24
INC-FW-22	2.2*	-19.0	.1	-39
INC-FW-25	-2.5	-1.4	.1	-46
INC-FW-29	2.4*	2.7	.8	24
INC-NFW-2	1.7	1.8	.9	46
INC-NFW-5	20.3*	18.0	1.0	48
INC-NFW-18	3.6	15.6	.8	25
INC-NFW-19	13.1*	14.9	1.0	47
INC-NFW-35	5.4*	2.4	.8	44
INC-NFW-37	3.5*	-.8	.4	0
DEC-FW-9	3.5	-2.0	.2	-15
DEC-FW-10	-1.2	3.8	.2	-20
DEC-FW-11	-5.5*	4.7	.4	28
DEC-FW-13	6.7	-3.5	.2	-7
DEC-FW-14	-.7	-.9	1.0	12
DEC-FW-15	2.5	-15.6	0	-27
DEC-FW-23	2.8	-3.6	.1	-1
DEC-FW-26	-3.5*	4.4	.7	18
DEC-FW-44	-2.4*	9.9	1.0	52
DEC-NFW-3	-5.9*	7.7	1.0	43
DEC-NFW-6	.4	-24.7	0	-54
DEC-NFW-8	-2.8*	4.3	1.0	22
DEC-NFW-12	6.1	-2.9	.2	-17
DEC-NFW-30	1.3	-5.4	.9	14
DEC-NFW-34	2.0	6.4	1.0	27
DEC-NFW-38	7.8	-8.2	0	-12
DEC-NFW-39	3.2	-2.6	0	-31

[a] Average change in heart rate in beats per minute during training. Significance determined by a one-sample t-test (one-tailed) of heart-rate changes on the training trials.

[b] Average bidirectional change (average increase minus average decrease) in heart rate in beats per minute during Transfer 2. Significance determined by a t-test (one-tailed, unequal variance) that compares increase performance to decrease performance.

[c] Proportion of judges correctly assigning an individual's open-ended report to correct training condition.

[d] Composite score from the rating scales that sums ratings for all relevant increase activities and subtracts ratings on all relevant decrease activities. Positive scores indicate an overall rating in the appropriate direction.

* $p < .05$

decrease heart rate was accompanied by significantly different reports of activities used to produce the response, as measured by the open-ended reports, the composite scores and the majority of the individual rating scales. The relationship between accurate self-report and bidirectional transfer was significant in the DEC-NFW group and approached significance in the INC-NFW group. Relations between self-report and response control did not differ between groups, either.

On the other hand, it might be argued that forewarning may have assisted accurate self-report. In particular, relationships between self-report and control were nonsignificant in the increase group when forewarning was omitted (group INC-NFW). However, this evidence of an effect of forewarning is not strong. Furthermore, all comparisons between the FW and NFW groups in terms of control in training and transfer, proportion of correct assignment, and scores on the rating scales proved nonsignificant. If forewarning of transfer does exert an influence on single-target training, it is a minor one.

Although the general trend of these data is consistent with a strong relationship between accurate self-report and control, there are exceptions to this rule. One type of exception are subjects who show evidence of accurate self-report without possessing control, suggesting that possessing veridical knowledge does not ensure control. Most of these subjects are found in the DEC groups (DEC-FW-14; DEC-FW-44; DEC-NFW-3; DEC-NFW-8; DEC-NFW-30; DEC-NFW-34). Other cases of veridical report without control occur in the INC-NFW group (INC-NFW-2; INC-NFW-5; INC-NFW-19) and are partly responsible for the overall lack of significant relationships in this group. Because virtually all INC-NFW subjects show some evidence of accurate self-report (i.e. only two subjects had their open-ended reports correctly assigned by fewer than 8/10 judges, and all subjects had a positive composite score), the subjects with the largest bidirectional heart-rate changes were not always the ones having the most veridical reports.

The more important exception to this relationship between accurate self-report and control concerns cases of control without accurate self-report. However, none of the three subjects with significant bidirectional transfer and inconsistent assignment of their open-ended reports provides unambiguous evidence of learning without awareness.

Finally, comparison of Experiments 1 and 2 suggests that inclusion of an initial transfer block preceeding training may facilitate control. Increase training performance is significantly higher in the INC group in Experiment 1 (with the initial transfer block) over the INC-FW group in Experiment 2 (without the initial transfer block), $\underline{t}(32) = 2.86$, $\underline{p} < .05$. However, this difference is confounded by the fact that subjects in Experiment 2 received slightly less monetary incentive.

CHAPTER 5: EXPERIMENT 3

Experiments 1 and 2 have demonstrated that the presence of accurate self-report and its positive relationship to heart-rate control are robust results not dependent upon bidirectional training or forewarning of transfer. These findings stand in contrast to previously cited experimental work. Two possibilities exist. Either knowledge was present in these earlier studies and the procedures used for detecting it were inadequate, or knowledge was indeed absent and there remains some important differences between the procedures employed in Experiments 1 and 2 and the early procedures that are responsible for this discrepancy.

Two of the remaining differences are the use of behavioural constraints and the presence of misleading cues. It was a common practise in the early studies to instruct subjects not to move around, tense muscles or alter breathing (Table 1). This was done to control for the possibility that autonomic ("involuntary") activity was being mediated by somatomotor or respiratory ("voluntary") behaviour. As pointed out in Chapter 2, the effectiveness of these procedures in eliminating such behaviour is suspect, as current evidence indicates most autonomic changes are subject to little alteration in the absence of such concomitant activities for the short training periods common in these studies (Marlin, 1984; Obrist, 1981). An examination of the six early heart-rate studies that employed behavioural constraints shows that attempts to verify compliance were limited to measurement of respiration alone and/or the subject's own report. Table 5 lists these six studies and details the training condition, the magnitude of control, the nature of the constraint(s), and the way in which compliance was verified. As can be seen, even with these minimal measures of verification there is evidence of noncompliance (Table 5).

The problem with constraining behaviours that are effective in producing autonomic control is that it might produce no control at all, or controllers reluctant to admit to having used these prohibited (but veridical) activities. Another possibility, however, is that instructional constraints might discourage gross somatomotor and respiratory events, but not subtler, less easily noticed alterations. The use of less salient somatomotor and respiratory activities might not have allowed subjects to recognize subtle systematic changes in these activities and therefore produced a genuine lack of awareness. Although constraints, by themselves, might not produce nonveridical reports in careful observers, they might do so in combination with other factors.

One such interacting factor concerns the nature of the experimental procedures. The procedures used in Experiments 1 and 2 were designed to reduce the potency of the task environment in overshadowing knowledge derivative from the feedback (i.e. subject-experimenter interaction is minimized; multiple electrode placements are used to avoid response cueing; and the response is only defined in terms of the feedback). This was not a concern of the early studies. In some studies the subject was given a distractor task to disguise the fact that he was involved in an autonomic learning experiment. In other cases subjects were deliberately misinformed about

Table 5: List of heart-rate studies employing behavioural constraints and reporting learning without awareness

1\. Brener & Hothersall (1966): INC/DEC (not reported; estimated difference between INC and DEC condition of 9 bpm)[a]

constraint	compliance
"S's specifically told not to engage in any bodily movements in their attempts to control the tones. Control was to be exercised by mental processes only".	--only respiration measured "The gross differences in respiratory patterns observed between...[increase]..and..[decrease] periods suggest the definite possibility that the observed HR control was mediated by changes in respiration".

2\. Engel & Hansen (1966): DEC (-1 bpm)[a]

constraint	compliance
"He was told the correct response was not related to breathing. He was also instructed to breathe normally because "abnormal breathing will foul up our measurements"".	--only respiration frequency measured --a t-test that compared breathing before training to during training found no significant differences "From our observations...it it not possible for us to infer any somatic mediators...the S who thought about exciting things and the S who aligned holes in the tiles both seemed to have increased their muscle tension... whereas the three other learners seemed to relax more".

3\. Engel & Chism (1967b): INC (+6 bpm)[a]

constraint	compliance
"He was told the correct response was not related to breathing. He was also instructed to breathe normally because "abnormal breathing will foul up our measurements"".	--only respiration frequency measured --2/5 S's found to have increased their respiration frequency "Our data do suggest that some of the experimental S's may have used somatic responses to facilitate their performance".

4\. Levene, Engel & Pearson (1968): INC/DEC (+5/-1 bpm)[a]

constraint	compliance
"The instructions were to lie as quietly as possible on the bed and not to change breathing because movement and abnormal breathing would "foul up our measurements"".	--only respiration measured "We are unable...to identify any somatic mediators for the control of HR. We did not see any gross musculo-skeletal maneuvers, and all S's reported they were able to cooperate with the instructions on this point. Although several S's showed phasic changes in breathing, we were unable to duplicate the HR changes by paced breathing..." [i.e. duplicating the breathing patterns and observing the HR changes]

5\. Shapiro, Tursky & Schwartz (1970): INC & DEC (+1 & -5 bpm)[a]

constraint	compliance
"S's were asked to breathe normally and to refrain from fidgeting or tensing muscles".	--only respiration measured "As to respiration, there were no consistent differences in breathing patterns as a result of direction of conditioning".

6\. Finley (1970): DEC (-2 bpm)[a]

constraint	compliance
"S's...warned against attempts to control by respiratory or muscular changes. They were told simply to breathe in and out and to avoid taking deep breaths, holding their breath, or breathing in other peculiar ways. They were [also] instructed not to...adjust their posture or flex their muscles". --in addition, HR changes accompanied by respiratory deviations were eliminated from the analysis	--only respiration amplitude and respiration frequency measured "partial correlation analysis of HR and respiration rate revealed nonsignificant covariation" --they suggest that because of a significant correlation with skin conductance "it is possible that the S's in this study successfully decreased their HR by using some sort of relaxation strategy. However, this could not be confirmed by post-experimental interviews".

[a]average change in heart rate during training

the purpose of the experiment or the utility or nonutility of certain activities. In the same manner as behavioural constraints, a misleading task environment might bias the subject's report and dilute its veridicality, or may disguise the processes actually involved and produce a genuinely nonveridical report. This likelihood is increased when the processes associated with autonomic change are not obvious, as is perhaps the case for constrained heart-rate subjects.

The intent of Experiment 3, then, was to provide a further assessment of the early studies that reported learning without awareness. This experiment looked at learning and self-report in two task environments similar to those of the early studies. In one, instructions discouraged the use of somatomotor and respiratory activity (Neutral (NEU)). In the second, instructional constraints were coupled with instructions and a electrode configuration that encouraged mental rather than somatic strategies (Mental (MEN)) (i.e. subjects were asked to influence the feedback by "mental means" and had only head electrodes).[6] Within each of these task environments one group received increase training (INC) and one group received decrease training (DEC). Subjects were not forewarned of transfer. If, with our more thorough verbal reporting procedures, accurate self-report is again obtained, it suggests assessment of the subject's knowledge in these earlier studies was inadequate. If accurate self-report is not obtained, or if there is unambiguous evidence of individual subjects controlling the response without reporting veridical information, this will support the contention that heart-rate control can proceed with limited awareness and establish some boundary conditions for the results and implications of Experiments 1 and 2.

METHOD

The method was the same as used in Experiment 2 except for the following differences.

Subjects

Fifty-two male volunteers from the McMaster University community and surrounding high schools, aged 15 to 34 (M = 20.6), received $3.00 per hour for their participation. Thirteen subjects were in each of the four groups.

Apparatus and Electrophysiological Recording

All apparatus and electrophysiological recordings were the same as in Experiment 1.

Subjects in the NEU group received the usual electrode placements but there were a number of changes for subjects in the MEN groups in order to eliminate body electrodes. In the MEN groups, measurement of heart rate was obtained by attaching a Hewlett-Packard #780-16 ear plethysmograph to the pinna of the left ear. Changes in blood density consequent upon each heart beat activated the Schmidt trigger on the clock of the PDP-11 which allowed for the continuous recording of successive IBIs to the nearest millisecond. Feedback was given for changes from the last recorded IBI during the pretrial period (the procedure of Experiment 1). Electrodes for measuring the electrocardiogram, electromyogram, skin conductance and the inactive themisters were omitted for all subjects in the MEN group. Two inactive Beckman electrodes (10 mm diameter) were attached to the lower left and lower right forehead for these subjects. These were in addition to the usual inactive electrodes attached to the upper left and upper right forehead.

Procedure

Subjects were randomly assigned to either the NEU or MEN condition prior to their arrival so that they would receive the appropriate instructions during the reception procedure. Subjects in the NEU condition received the standard reception procedure of Experiments 1 and 2, which stated that the purpose of the experiment was "to teach you to control a response not normally thought of as being controlled voluntarily". Subjects in the MEN condition, however, were told that "the experiment today attempts to teach you to control by mental means a dash that will appear on a television screen".

During the electrode attachment all subjects were told by the experimenter "These are very sensitive electrodes. It is very important that you do not do anything that will produce artifactual and erroneous recordings. Therefore, do not move around, flex your muscles or breathe abnormally, and do not touch or put pressure on the electrodes". Subjects were told the constraints on somatomotor and respiratory activities were to avoid artifact, so as not to suggest these activities might be of potential use in producing the response. The electrode test to check for artifact and the proper functioning of the electromyogram and movement was omitted for all subjects because of the incompatibility of this test with the above instruction not to move around. Once proper electrophysiological signals were obtained, subjects in both the NEU and MEN groups were randomly assigned to either an INC or DEC training condition.

Tape recorded instructions (Appendix J) for subjects in the NEU groups were identical to those of the NFW condition in Experiment 2, with the exception that during the first set of instructions they were again asked to "remain still, breathe normally, and avoid flexing your muscles so as to avoid producing artifact in these sensitive recordings". Subjects in the MEN groups were told that the purpose of the experiment was to test their ability to mentally control the movements of a dash on a television screen, and that they should use mental means to move the dash as far as possible in the direction of the letter A. Subjects in this group were similarly instructed to remain still, breathe normally and avoid flexing muscles. Instructions for MEN subjects in Transfer 1 asked them to "continue to do whatever you found useful in mentally moving the dash up even though the dash will not be available to tell you how successful you have been". Transfer 2 instructions asked these subjects to "mentally" move the dash in the direction of the letter A as in Transfer 1, but also, on B-trials to "mentally" move the dash in the opposite direction.

Post-training reports

All subjects were given the written questionnaires (Appendix K) following Transfer 2. The first questionnaire asked subjects to describe what they did "to make the dash move in the direction of the letter A on A-trials" and what they did on B-trials "to make the dash go in the opposite direction". The second questionnaire asked subjects to rate, by means of quantitative scales, the extent to which he used anxious thoughts, calming thoughts, exciting thoughts and blank mind in moving the dash. In addition to these questionnaires (which were used in Experiments 1 and 2), a third questionnaire was given. This questionnaire asked subjects to indicate whether they thought that somatomotor and respiratory activities might have been useful in moving the dash, whether they used them or not. If they responded yes to this question, they were instructed to rate on quantitative scales the potential or actual usefulness of the following specific activities: tensing muscles, relaxing muscles, rapid breathing, slow breathing, moving around in the chair, and keeping very still. The third questionnaire (and the wording of the rating scales therein) was used to allow for the possibility that failure to obtain veridical report on the other questionnaires might be due to a reluctance to report veridical information, rather than a genuine lack of awareness.

The sorting task for the open-ended reports was the same as in Experiment 2 and again employed ten judges. The instructions for the judges is contained in Appendix L.

Data Reduction

Seven subjects were eliminated from the analysis because of equipment failure ($n = 3$), procedural inconsistencies ($n = 1$) and excessive artifact in their physiological recordings ($n = 3$). Four of these subjects were in the INC-MEN group, two in the DEC-NEU group and one in the INC-NEU group. For the remaining 52 subjects respiration was rejected for seven subjects and skin conductance for three subjects. Fewer than 1% of all remaining individual trials were eliminated because of artifact. The relationship between heart rate and the concomitant responses was examined and found to be similar to that obtained in

Experiments 1 and 2. For ease of presentation this data is presented in Appendix N rather than in the result section. Group heart-rate changes in Transfer 2 are presented in Appendix M for the same reason.

RESULTS

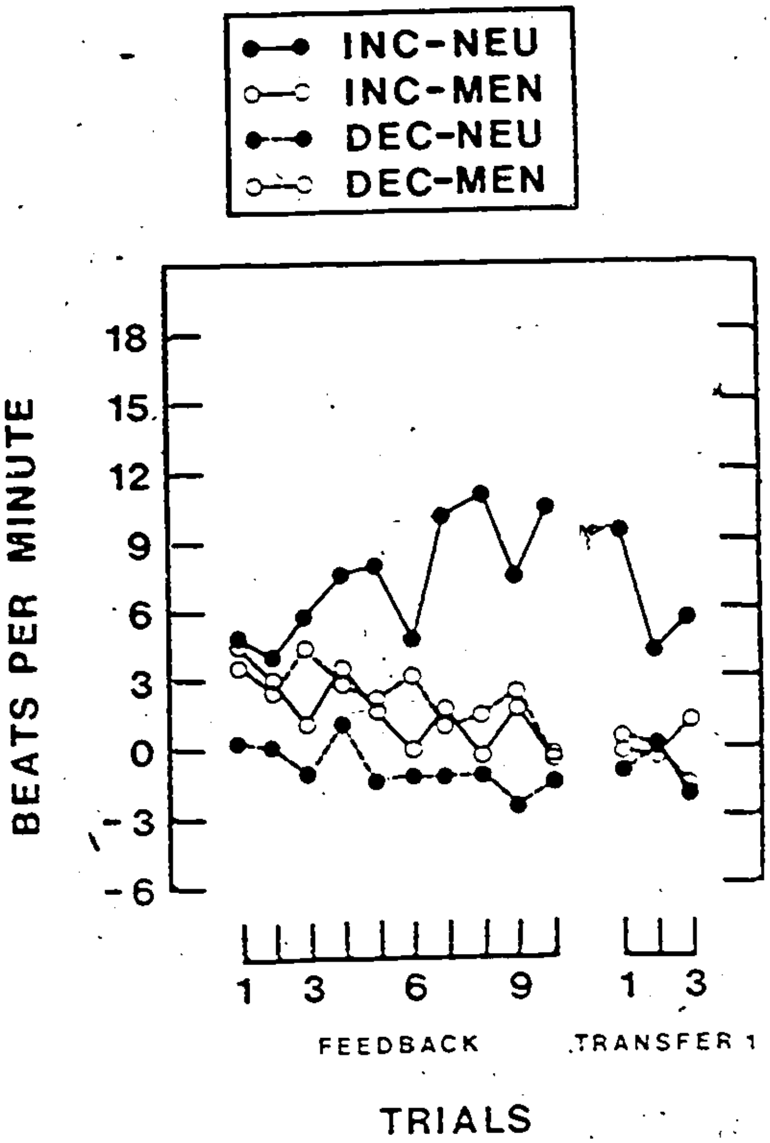
Heart-rate control

Control of heart rate on feedback trials and during Transfer 1 is shown for each group in Figure 4. Analysis of variance revealed a significant overall main effect of target condition (INC vs. DEC) in training, $\underline{F}(1,48) = 5.28$, $\underline{p}<.05$. Average heart-rate change was 4.5 bpm in the INC groups and .6 bpm in the DEC groups. An interaction between instructional condition (NEU vs. MEN) and target condition, $\underline{F}(1,48) = 7.39$, $\underline{p}<.05$, revealed that this difference was largely due to the performance of the INC-NEU group. A Tukey test indicated that the average increase in heart rate in the INC-NEU group (7.4 bpm) was significantly higher than that of the INC-MEN group (1.5 bpm).

In Transfer 1 a main effect of target condition was again obtained, $\underline{F}(1,48) = 4.58$, $\underline{p}<.05$. The average change was 3.2 bpm in the INC groups and -.6 bpm in the DEC groups. The interaction between target condition and instructional condition only approached significance, $\underline{F}(1,48) = 3.31$, $\underline{p}=.07$. No interactions between target condition and trial number were found in either training or Transfer 1. In addition, decrease performance did not differ from blank trial performance in any group.

Kolmogorov-Smirnov tests found no significant differences in the ratings of perceived success between the INC and DEC group within either

Figure 4. Heart-rate changes from pretrial baseline during feedback training and Transfer 1 in Experiment 3. Increase trials are represented by solid lines and decrease trials are represented by broken lines. The Neutral groups are represented by solid circles and the Mental groups are represented by open circles.


INC-NEU
INC-MEN
DEC-NEU
DEC-MEN
BEATS PER MINUTE
18
15
12
9
6
3
0
-3
-6
1
3
6
9
1
3
FEEDBACK
TRANSFER 1
TRIALS

Figure

the NEU or MEN conditions ($\underline{M}_{INC-NEU} = 2.5$; $\underline{M}_{INC-MEN} = 2.2$; $\underline{M}_{DEC-NEU} = 2.2$; $\underline{M}_{DEC-MEN} = 1.6$).

Post-training reports

A Kolmogorov-Smirnov test (one-tailed) found no difference between groups INC-NEU and DEC-NEU in the proportion of judges assigning reports to increase training condition, $\underline{D}(13) = 3$, $\underline{p} > .05$. Similarly, within the MEN condition, assignment of INC-MEN reports to the increase condition was not significantly different from the assignment of DEC-MEN reports, $\underline{D}(13) = 2$, $\underline{p} > .05$. The average proportion of judges who assigned a report to the increase training condition within each group was as follows: INC-NEU = .74 (i.e. 7.4/10 judges); DEC-NEU = .62; INC-MEN = .75; DEC-MEN = .71.[7]

However, the same statistical procedure applied to the scale ratings within the NEU condition found the following scales to differentiate between the INC and DEC groups: relaxed muscles ($\underline{D}(13) = 7$, $\underline{p} < .05$), rapid breathing ($\underline{D}(13) = 7$, $\underline{p} < .05$) and slow breathing ($\underline{D}(13) = 7$, $\underline{p} < .05$). The composite scale was also significantly different, $\underline{D}(13) = 6$, $\underline{p} < .05$. Within the MEN condition, however, none of the individual scale ratings were found to be significantly different between the INC and DEC groups. The composite scale was also nonsignificant, $\underline{D}(13) = 2$, $\underline{p} > .05$.

Comparisons between the NEU and MEN conditions found no differences between the DEC-NEU and DEC-MEN groups in either the open-ended reports or the scale ratings. For the INC groups, however, the situation was different. Subjects in the INC-NEU group reported a greater use (or recognition of the potential use) of rapid breathing

($D(13) = 7$, $p<.05$) and slow breathing ($D(13) = 6$, $p<.05$). Larger overall composite scores were also obtained in the NEU group, $D(13) = 6$, $p<.05$.

Relationship between control and self-report

Despite the failure of the open-ended reports to differentiate between the INC and DEC groups, significant correlations between proportion of correct assignment by the judges and magnitude of bidirectional transfer were obtained in three groups: INC-MEN, rho =.75, $p<.05$; DEC-NEU, rho =.57, $p<.05$; DEC-MEN, rho =.48, $p<.05$. However, this correlation was not significant in group INC-NEU, rho = .21, $p>.05$.

Scores on the rating scales were also correlated with bidirectional control in Transfer 2. For the INC-NEU group there were significant relationships for the following: tensed muscles (rho = .56, $p<.05$), relaxed muscles (rho = .71, $p<.05$), slow breathing (rho = .52, $p<.05$), exciting thoughts (rho = .50, $p<.05$), and the composite score, rho = .52, $p<.05$. In the INC-MEN group there were significant relationships for tensed muscles (rho = .59, $p<.05$), relaxed muscles (rho = .58, $p<.05$), slow breathing (rho = .78, $p<.05$), rapid breathing (rho = .56, $p<.05$), keeping still (rho = .51, $p<.05$), calming thoughts (rho = .51, $p<.05$), anxious thoughts (rho = .80, $p<.05$), and the composite score, rho = .80, $p<.05$. In the DEC-NEU group there was a significant relationship for anxious thoughts (rho = .56, $p<.05$) and the composite score, rho = .51, $p<.05$. In the DEC-MEN group there were significant relationships with rapid breathing (rho = .50, $p<.05$), movement (rho = .54, $p<.05$), and the composite score, rho = .51, $p<.05$.

A final analysis attempted to determine if there was evidence of individual subjects having controlled the response without accurate self-report. Subjects were divided up into differentiators and nondifferentiators on the basis of their bidirectional transfer performance, and into those showing evidence of accurate self-report and those not on the basis of whether nine out of ten judges correctly assigned the subject's verbal report to training condition. Of the eight subjects who controlled the response, all but INC-NEU-47 had their open-ended reports consistently assigned to training condition. Because this one exception is an INC subject, an elicited basis for his heart-rate performance cannot be ruled out. Also, a lack of veridical content in the open-ended report might be due to a reluctance to report somatomotor and respiratory activities. This subject has a composite score of 12 on the scales that ask about the potential usefulness of these activities.

A summary of the performance of all individuals in Experiment 3 is contained in Table 6.

DISCUSSION

Control of heart rate in the MEN conditions of Experiment 3 was significantly poorer than the NEU conditions of this study. This effect was largely confined to subjects trained to increase heart rate and was evidenced by smaller heart rate increases in training and composite scores that were significantly lower in the MEN condition. This result illustrates the importance of the subject's task environment in producing heart-rate control. Subjects in the MEN condition had

Table 6: Summary of individual performance in Experiment 3

DIFFERENTIATORS

Subject	Train bpm[a]	bidir. Trans. bpm[b]	PCA[c]	COMP[d]	Y/N[e]
INC-NEU-32	26.4*	31.7*	1.0	34	Y
INC-NEU-39	15.3*	28.8*	.9	44	Y
INC-NEU-47	19.9*	29.6*	.2	12	Y
INC-MEN-19	3.1	18.0*	.9	22	Y
INC-MEN-35	2.3*	13.0*	1.0	32	Y
INC-MEN-50	-.9	4.5*	.9	26	Y
INC-MEN-57	2.4*	9.4*	1.0	32	Y
DEC-NEU-45	-1.3	8.7*	1.0	38	Y

NONDIFFERENTIATORS

Subject	Train bpm	bidir. Trans. bpm	PCA	COMP	Y/N
INC-NEU-1	-1.4	5.0	1.0	21	Y
INC-NEU-3	.4	.5	.6	12	Y
INC-NEU-7	-3.5	-2.1	.5	6	Y
INC-NEU-13	8.0*	12.6	1.0	34	Y
INC-NEU-22	10.3*	4.2	.4	7	Y
INC-NEU-27	3.6	15.8	1.0	46	Y
INC-NEU-43	15.4*	13.1	.8	14	Y
INC-NEU-44	.2	-5.1	.9	24	Y
INC-NEU-53	-.5	-4.1	.9	12	Y
INC-NEU-59	1.9*	3.6	.4	8	Y
INC-MEN-10	4.6*	1.3	.8	3	N
INC-MEN-11	-5.7	-9.8	.6	-2	Y
INC-MEN-15	-4.0	-6.7	.1	-15	Y
INC-MEN-28	3.6*	-2.4	.8	5	Y
INC-MEN-31	15.9*	3.4	.6	0	Y
INC-MEN-37	-2.8	-4.7	.5	1	Y
INC-MEN-38	1.1	-5.6	.6	4	Y
INC-MEN-56	-1.2	-3.3	.9	5	Y
INC-MEN-55	1.7	3.3	1.0	10	Y
DEC-NEU-2	1.2	-1.4	.2	-12	Y
DEC-NEU-6	2.2	-3.7	.3	-15	Y
DEC-NEU-14	-3.0	1.8	1.0	34	Y
DEC-NEU-17	.8	-1.0	.1	-21	Y
DEC-NEU-23	-3.4*	-5.4	.1	-7	N
DEC-NEU-33	-2.2*	1.4	.2	-17	Y
DEC-NEU-36	.5	.7	1.0	34	Y
DEC-NEU-46	-.6	-4.9	0	-29	Y
DEC-NEU-48	-7.7*	-4.8	.6	27	Y
DEC-NEU-51	1.0	-4.0	0	-4	Y
DEC-NEU-54	1.1	1.8	.2	4	Y
DEC-NEU-55	-2.6*	-1.2	.3	-3	Y
DEC-MEN-8	.8	1.8	.1	-20	Y
DEC-MEN-12	3.6	.9	.3	-11	N
DEC-MEN-16	.5	-5.1	.6	-2	Y
DEC-MEN-18	17.5	-8.4	.1	-12	N
DEC-MEN-21	-1.4*	-11.3	.4	-1	N
DEC-MEN-24	0	10.9	.9	39	Y
DEC-MEN-29	1.5	3.0	.5	8	Y
DEC-MEN-30	.6	-.7	.2	-32	Y
DEC-MEN-34	1.0	4.9	.6	2	Y
DEC-MEN-40	3.9	-6.3	0	-11	Y
DEC-MEN-41	2.3	-1.3	.1	1	N
DEC-MEN-42	-.3	-10.3	0	-39	Y
DEC-MEN-52	-1.4*	1.1	0	-10	N

[a] Average change in heart rate in beats per minute during training. Significance determined by a one-sample t-test (one-tailed) of heart-rate changes on training trials.

[b] Average bidirectional change in heart rate in beats per minute during Transfer 1. Significance determined by a t-test (one-tailed, unequal variance) that compares increase performance to decrease performance.

[c] Proportion of judges correctly assigning an individual's open-ended report to training conditions.

[d] Composite score from the rating scales.

[e] Indicates whether the subject believed that respiratory activities and/or somatomotor activities were (Y) or were not (N) useful in influencing the feedback dash.

* $p < .05$

identical feedback contingencies to subjects in the NEU condition, but a difference in electrode configuration and instructional orientation produced a significant difference in control and self-report.

However, even though the mentalistic task environment interfered with successful control of heart rate, control and response awareness were still related. Nonsignificant differentiation of heart rate between the INC and DEC groups during training was accompanied by nonsignificant differentiation of the open-ended reports, the composite scale, and all of the individual rating scales. Despite the small number of controllers within this condition, the relationship between self-report and control was significant for the open-ended reports, composite scale, and a number of individual scales for both the INC and DEC groups. The four individual learners in this condition all had their open-ended reports consistently assigned to the correct training condition, reported that respiratory and/or somatomotor activities were relevant, and had large positive composite scores.

The results of the NEU condition support similar conclusions about the relationship between bidirectional control and accurate self-report. In the DEC-NEU group, significant relationships between self-report and control were obtained for both the open-ended reports and the composite scale, and the single subject in this group with significant bidirectional control had his open-ended report correctly assigned by all ten judges and had a large positive composite score. For the INC-NEU group the relationship with the open-ended reports, although in the correct direction, was nonsignificant. However, it is possible the lack of veridical content in the open-ended reports is due to a reluctance to report respiratory and/or somatomotor strategies because of the instructional constraints on these activities. The nonsignificant differentiation of the open-ended reports between INC-NEU and DEC-NEU despite significant heart-rate differentiation might also be due to this. The rating scales where subjects were asked to assess the potential usefulness of specific veridical activities were significantly related to control and significantly differentiated between INC and DEC training conditions. Three out of four INC-NEU subjects with significant bidirectional control had their open-ended reports consistently assigned and all four had large positive composite scores.

In summary, the basic finding of this experiment is that even when constraints and misleading cues are present and result in poorer control (more in line with with heart-rate changes seen in the early studies) and less frequent veridical knowledge, the positive relationship between self-report and bidirectional transfer is still maintained. Significant correlations were obtained in three of the four groups for the open-ended reports and in all four groups for the composite scales, and seven out of eight individual subjects with bidirectional control evidenced accurate self-report by virtue of consistent assignment of their reports.

CHAPTER 6: GENERAL DISCUSSION

SUMMARY OF RESULTS

The question this thesis addresses is whether conscious awareness of response activities related to variations in heart rate is necessary for learned control of heart rate to occur. Early research concerning this issue supported a view that learning could occur without awareness (Engel, 1972; Kimmel, 1974). However, recent research using more thorough methods of assessing learning and awareness has found learning to be reliably related to veridical self-report (Roberts et al., 1984). It would appear this discrepancy is either due to inadequate methods of assessment in the early studies or to procedural differences between the early and recent research. The intent of this thesis was to evaluate these two possibilities. Three experiments were conducted that utilized more thorough methods of assessment while examining procedural differences between early and recent research that might affect the relation between learning and response awareness. The third experiment used two task environments that approximated the procedures employed in the earlier studies. The results are as follows.

In Experiment 1, heart-rate differentiation between the INC and DEC group during feedback training and transfer was accompanied by significant differentiation of both the open-ended verbal reports and the composite rating scale. Heart-rate differentiation between the increase target and the decrease target within the INC/DEC group was similarly accompanied by significant differentiation of both the open-ended reports and the composite scale. The relationship between self-report and the magnitude of bidirectional heart-rate control in training in the INC/DEC group was significant for both the open-ended reports and composite scale. There were ten subjects who achieved significant bidirectional control in training in the INC/DEC group, and all had their open-ended reports consistently assigned to correct training condition. The important finding of Experiment 1 is that no differences between the one and the two-response groups were obtained in terms of magnitude of control or veridicality of the reports, indicating the procedural variable of bidirectional versus unidirectional training is not likely responsible for the discrepancy with the early research.

In Experiment 2, heart-rate differentiation between the INC and DEC groups within both the FW and NFW conditions was accompanied by significant differentiation of both the open-ended reports and composite scale. The relationship between accurate self-report and the magnitude of heart-rate control in bidirectional transfer was significant in three of the four groups for both the open-ended reports and composite scale. These relationships only approached significance in the INC-NFW group. Of the sixteen subjects with significant bidirectional transfer, thirteen had their open-ended reports correctly assigned to training condition by at least nine out of ten judges. The important finding of Experiment 2 is that no significant differences were obtained between the FW and NFW conditions in either control or self-report, indicating the procedural variable of forewarning or not forewarning subjects of transfer is not likely responsible for the discrepancy with the early research.

In Experiment 3, two task environments were used that approximated those used in the early research. Subjects were trained on one response, received no forewarning of transfer, and were instructed not to use somatomotor or respiratory activity to control the response (groups INC-NEU and DEC-NEU). In addition, half the subjects were encouraged through verbal instructions and electrode placements to solve the task by mental strategies (groups INC-MEN and DEC-MEN). Nondifferentiation of heart rate within the MEN condition was accompanied by nondifferentiation of the open-ended reports and nondifferentiation of the composite scores. In the NEU condition, differentiation of heart rate in training and transfer was accompanied by nondifferentiation of the open-ended reports but differentiation of the composite scores. The relationships between bidirectional control in transfer and the open-ended reports were significant in all but the INC-NEU group. The relationships between bidirectional control and the composite scores were significant in all four groups. Seven out of eight subjects with significant bidirectional transfer had their open-ended reports correctly assigned. An important finding of Experiment 3 is that the mentalistic orientation of the MEN condition produced significantly poorer control and lower composite scores in the INC-MEN group as compared to the INC-NEU group. Despite this, the relationship between self-report and control was maintained.

These results indicate a strong relationship between learning as measured by bidirectional control and response awareness as measured by accurate self-report. Significant relationships were obtained between these two variables in the majority of the situations where it was assessed. The larger the magnitude of control, the larger were the scores on the rating scales, and the greater was the number of judges who assigned the open-ended report to correct training condition. Of the 34 subjects judged to have controlled the response in the three experiments, 30 had their open-ended reports assigned to correct training condition by at least nine out of ten judges and all 34 had positive composite scores. Furthermore, this relationship between self-report and control is not dependent upon bidirectional training, forewarning of transfer, behavioural constraints, or a mentalistic orientation. In task environments designed to approximate the early research, poorer control and less accurate reports were produced, but the relationship between these two variables was still maintained.

The implication of these findings is that, at least for heart-rate learning, the lack of awareness found in the early studies is likely due to the failure of these studies to adequately assess response awareness rather than due to procedural differences with recent research that influenced the presence of awareness.

RELEVANCE TO MODELS OF THE VISCERAL LEARNING PROCESS

How do these results bear on the different models of the visceral learning process? Concerning control performance, there are several phenomena that are not well explained by a strict operant account. For example, operant conditioning does not explain the fact that subjects in these experiments with identical feedback contingencies and response organizations produce widely different heart-rate control.

Nor does it explain why some subjects receiving feedback for decreases in heart rate actually end up producing significant overall increases. Operant conditioning does not explain why decreases in heart rate are consistently more difficult to produce, and it does not explain the lack of acquisition curves for any of the individual groups in Experiments 2 and 3. This latter result (which is consistent with most heart-rate studies that show very rapid or immediate acquisition (Yates, 1980)), also provides difficulty for ideomotor theory which predicts progressive "calibration" and motor skills theory which predicts gradual skill development. On the other hand, if the biofeedback situation is conceptualized as a problem to be solved, as is the case with the problem-solving framework, instantaneous changes are not unexpected.

Also important is operant conditioning's inability to explain why a consistently good predictor of this variability in control is the subject's awareness of the response. Subjects who do not control typically do not give accurate self-report and subjects who do control typically do. This is a result more compatible with models such as ideomotor theory, motor skills and problem solving that predict a close association between response awareness and control. A problem for ideomotor theory, however, is that it predicts a perfect association between response awareness and control. It cannot explain subjects in these experiments who show evidence of accurate self-report but do not control the response.[8]

Correlation does not imply causation, and this close association between veridical report and control does not necessarily mean that verbal awareness of the response or conscious processing was involved in the development of control as is implied by models such as motor skills and problem solving. For example, a modified operant account might suggest that accurate self-report following successful visceral training is the result of the automatic accumulation of response memories associated with reward. Another possibility is that, when subjects who learn to control the response are subsequently asked to report how they achieved control, they provide accurate report either by a retrospective analysis of their performance or by relying on a priori theories about how autonomic changes are produced (Nisbett & Wilson, 1977). However, there are several points that argue against verbal awareness being either a by-product of control or the result of retrospective deduction.

One is the scope of the subject's knowledge. The fact that subjects in these and other experiments (e.g. Roberts et al., 1984; Hughes & Roberts, 1985) commonly report things that do not work, in addition to things that do work, rules out the possibility that accurate report is produced by an accumulation of only success-related memories.

Furthermore, if verbal awareness is peripheral to the process involved in the development of control, then it is reasonable to expect that manipulations designed to influence the subject's verbal awareness or cognitive orientation should not affect control. There are several phenomena in the field of visceral learning that demonstrate just the opposite. Within the present series of experiments, the mentalistic orientation used in Experiment 3 resulted in poorer heart-rate control in the INC-MEN group as compared to the INC-NEU group that was not given misleading strategy suggestions. With one or two exceptions (Johnson &

Schwartz, 1967; Lacroix & Roberts, 1978), previous studies have shown that misleading or inadequate instructions interfere with learning (e.g. Bell & Schwartz, 1973; Berger, 1973; Bergman & Johnson, 1972; Blanchard, Scott, Young & Edmundson, 1974; Brener, 1974a; Lang, Sroufe & Hastings, 1967). A related finding is that correct response information usually facilitates learning. For example, simply instructing subjects to produce heart-rate increases or decreases without any experience at feedback training often produces heart-rate control (e.g. Bergman & Johnson, 1971; Blanchard, Young, Haynes & Scott, 1975; Blanchard, Young, Scott & Haynes, 1974). Similarly, training subjects to discriminate the response prior to feedback training usually results in improved autonomic control relative to prediscrimination control or to groups that did not receive discrimination training (Brener, 1974a; McFarland 1975; McFarland & Campbell, 1975; Penzien & Appel, 1982).

A final demonstration of the importance of the subject's cognitive orientation in the development of control is found in an experiment by Hughes & Roberts (1985). These investigators found that successful visceral control could be predicted by probing the subject's conceptualization of the task ("problem space") prior to training. Subjects trained in a similar manner to the experiments reported in this thesis were asked prior to training "How do you plan to go about controlling the response?". The number of strategies a subject reported, and the extent to which it was judged that he had a well formulated plan, were significantly correlated with subsequent heart-rate control. Subjects who achieved control, unlike subjects who failed to achieve control, typically had a well formulated plan of action and had a number of specific strategies they planned on testing.

The above evidence suggests that the subject's verbal awareness and cognitive orientation have a role to play in the development of visceral control and that the close associations between these two things seen in the present experiments is not likely due to awareness being an incidental by-product or a retrospective deduction. This result and these phenomena encourage a view of the organism as a problem solver that develops and evaluates strategies and whose conceptualization of the task influences success.

Although a problem-solving orientation would appear to be an appropriate framework to understand heart-rate learning, a few qualifications need to be made. The first is that this result does not necessarily apply to tasks other than heart-rate learning. A response such as heart rate is influenced by a number of salient, easily controlled and easily reported somatomotor and respiratory activities. It is only a small minority of subjects in the present three experiments (17/144) who report they succeeded by "increasing or decreasing their heart rate". The rating scales that differentiated most frequently between increase and decrease conditions were muscle tension, muscle relaxation, rapid breathing and slow breathing. In retrospect it is not suprising that when such salient activities that are commonly associated with conscious cognitive initiation are employed, they are also mentioned in a verbal report, and that subjects who fail to mention them have also failed to discover their utility and control the response. On the other hand, it is conceivable that training on other physiological responses without such salient concomitants such as EEG patterns or electrodermal activity may not produce such accurate reports. Here again, however, the results of the few studies that have employed thorough assessment procedures for these particular activities support the awareness view (Roberts et al., 1984, Expt.2; Mandryk, 1985; Plotkin, 1976; Schwartz, Davidson & Pugash, 1976).

A second qualification is that these results do not necessarily apply to long term training situations. Initial stages of learning are believed to involve a high degree of conscious mediation whereas the phenomenology of highly learned motor (Fitts & Posner, 1967), social (Langer, 1978) and various types of cognitive skill (deGroot, 1965; Anderson, 1982) is quite minimal. It is possible that heart-rate training for considerably longer periods would produce more specific heart-rate control dissociated from somatomotor and cognitive concomitants. The evidence concerning specificity in long term autonomic training is controversial (Kimmel, 1982; Marlin, 1984; Miller, 1978; Miller & Brucker, 1979; Yates, 1980).

A final qualification is that the importance of conscious processing in heart-rate learning does not negate the importance of biological or motivational considerations. In this respect the biofeedback situation is not much different from many other tasks humans encounter. Knowing how to do something after a training experience does not mean that you will do it or even that you could do it if you wanted to. The fact that accurate self-report without control occurs mostly for subjects trained on decreases illustrates biological limitations. Decreases in heart rate are difficult to produce because the subject is usually trained in a nonactive situation where his heart is already in its resting state. He may quickly realize and be able to report the incompatibility of active movements and the compatibility of relaxation to success, but be unable to produce a significant degree of physiological quiescence beyond what he is already experiencing. Subjects trained to produce increases, on the other hand, once they recognize (and can report) the importance of somatomotor and/or respiratory events, usually have no difficulty in producing significant increases in heart rate.

FOOTNOTES

1. Miller & Brucker (1979) have found some dissociation for much longer training periods. See also Marlin (1984), Miller (1978), Kimmel (1982) and Yates (1980) for summaries of the evidence concerning specificity of control.

2. This statement applies only to analyses (such as of central tendency or correlation) in which the group as a whole is considered. In these analyses the presence of multiple independent subjects (minimum $\underline{n}$ = 10) diminished the probability that the content of the report was adventitiously associated with the proper trial cue. The veridicality of individual reports, on the other hand, is subject only to descriptive interpretation because the report could have been attributable to guessing.

3. A composite score is less legitimate for the purposes of correlation with control because it implies that subjects who tensed + moved + hyperventilated + used exciting thoughts should be the subjects producing the largest heart-rate increases. Although there may be some truth to this, it is also true that very large and perhaps asymptotic heart-rate changes can be achieved using only one or two of these strategies.

4. Experiment 2 was actually run prior to Experiment 1. However, the results of the studies were such that the present ordering made a more natural progression.

5. Roberts et al. (1984) reported four subjects who controlled the

response without being correctly assigned to training condition by at least 9/10 judges. The reason for this discrepancy is that the t-tests used in this thesis to assess control assume unequal variance between increase and decrease trials, whereas the t-tests employed by Roberts et al. (1984) assume equal variance.

6. A mentalistic orientation was used by some of the early studies (Table 1) and it capitalizes on an already existing tendency for some subjects to interpret the task as a telekinesis experiment requiring them to will the dash up with their minds. Three subjects in Experiment 1 and two subjects in Experiment 2 had open-ended reports that contained a single nonveridical strategy of "concentration on moving the dash" or "willing the dash up". Up to this point, these subjects have failed to demonstrate control of the response, or if they have, they report veridical activities in the rating scales. Nevertheless, a purer case of learning without awareness may be obtained if there are more subjects oriented in this direction.

7. The basis for nonsignificant differentiation of the open-ended reports resides with the DEC groups. Average proportion of assignment to the increase training condition for the INC-NEU group (.74) is not much different from that obtained with the INC-NFW group in Experiment 2 (.80). On the other hand, average proportion of assignment to the increase condition for the DEC-NEU group (.62) is considerably higher than that obtained for the DEC-NFW group (.40). This same phenomenon of most DEC subjects being assigned to the increase training condition is more pronounced in the DEC-MEN group (.71), and is significantly different from that of the DEC-NFW group in Experiment 2, $D = .46$,

$p < .05$. This is puzzling since a total lack of veridical knowledge in any group should theoretically produce an average proportion of correct assignment approximating .50. The explanation is that 44% of subjects in both the NEU and MEN conditions had open-ended reports containing a single nonveridical mentalistic strategy of "concentration on moving the dash" or "willing the dash up". (This compares to 6% in Experiment 1 and 5% in Experiment 2). On the basis of this information alone, judges assigning these reports to training condition preferentially chose the increase condition (*M* = .71). This inflated overall correct assignment for INC subjects, but deflated overall correct assignment for DEC subjects.

8. The measure of awareness ideomotor theory is strictly concerned with is the ability to recognize the afferentation or internal sensations consequent upon behavioural change. The relationship between this type of awareness and the verbal awareness assessed in these experiments is not clear. If ideomotor theory restricts itself to predicting relationships between afferentation recognition and control, then accurate self-report without control is not necessarily a problem.

APPENDIX A

Initial Interview Form (Confidential)

NAME: SEX:

TELEPHONE NUMBER: AGE:

OCCUPATION: WEIGHT:

WITH WHICH HAND DO YOU WRITE: HEIGHT:

Have you ever taken part in an experiment in which physiological recordings were made? If so, give details. (If biofeedback, reject. Were you trained to control the response? Were you given feedback? If so, reject).

Have you smoked, had coffee or an alcoholic beverage in the last 1/2 hour? (Note, if nicotine or caffeine. Reject, if alcohol)

Are you presently taking any medications?
- antibiotics? (o.k. but note)
- antihistamines? (o.k. but note)
- psychoactive drugs? (reject)
- other? (if psychoactive, reject)

Have you had any respiratory disorders, e.g. asthma or bronchitis? (If current, reject)

Have you had any skin conditions, e.g. eczema, blistering? (If current and located on a potential electrode site, reject)

Are you diabetic? (reject)

Are you epileptic? (reject)

Have you ever had any heart or cardiovascular problems?
- arrhythmia or heart attack? (reject)
- angina or murmur? (if current and physical activities restricted, reject)
- rheumatic fever? (reject)
- ever had an electrocardiogram? (if for diagnostic purposes, reject)
- high blood pressure? (reject)

Blood Pressure: ....../...... (Taken by experimenter with standard blood pressure cuff, sphygomanometer and stethoscope) (if > 130/90, reject)

Neurological examination
- balance on one foot
- with eyes closed and arm outstretched, touch index finger to nose
- touch finger to location of tongue inside cheek
- subject to any fainting spells or dizziness? (reject)

Do you smoke? (note)

Date..................

APPENDIX B

Instructions for subjects in Experiment 1: INC and DEC groups

In this experiment we are going to teach you to control a physiological response that is not usually thought of as being controlled voluntarily. For convenience we will call this response, Response A. The training procedure will be as follows.

From time to time a horizontal line and a small vertical dash will appear in the center of the television screen in front of you. Above the line and dash will appear the letter A. A typical display will look like this (sample). The horizontal line represents your level of physiological rsponding at the start of each trial. Movements of the dash away from this horizontal line, on the other hand, will be produced by the physiological response you are to control. Your task is to move the dash as far as possible in the direction of the letter A. If possible, do not allow the dash to fall below the horizontal line after the trial has begun. Instead, move it as far as you can in the direction of the letter A. When there is no visual display on the screen, you should rest and wait for the next trial.

We are going to begin by giving you twelve trials on which you are to move the dash toward the A. However, in addition to these trials we are going to give you some test trials on which the letter A will appear, but the dash and horizontal line will not be presented. On test trials the display will look like this (sample). You should attempt to produce the required response as best you can on test trials, even though the dash will not be available to tell you how successful you have been. Test trials will be given at the beginning of the session and again when the session is finished. You will of course be puzzled as to what you should do on test trials given at the beginning of the session since at this time you will not have had an opportunity to learn about Response A from the feedback dash. We ask that you simply do the best you can. Our purpose in giving you test trials at the outset is to illustrate what will be required when the session is finished.

Feel free to use any method you wish to produce Response A but please do not touch or put pressure on the electrodes we have attached to your body. This will create artifact in our recordings.

To provide extra incentive we are going to pay you bonus money for performing successfully. You could earn up to $2.00 in bonus money if you do well. You will be told how much bonus money you have earned when the session is finished.

If you would like these instructions repeated, please tell us now. Otherwise, the experiment will begin in two or three minutes.

Instructions for subjects in Experiment 1: INC/DEC group

In this experiment we are going to teach you to control two physiological responses that are not usually thought of as being controlled voluntarily. For convenience we will call one response, Response A, and the other response, Response B. The training procedure will be as follows.

From time to time a horizontal line and a small vertical dash will appear in the center of the television screen in front of you. Above the line and dash will appear the letter A or the letter B. These letters indicate to you which physiological response, Response A or Response B, you are to control. A typical display will look like this on A-trials (sample) and like this on B-trials (sample). The horizontal line represents your level of physiological responding at the start of each trial. Movements of the dash away from this horizontal line, on the other hand, will be produced by the physiological response, Response A on A-trials, or Response B on B-trials, that you are to control. Your task is to move the dash as far as possible in the direction of the letter A on A-trials and to move the dash as far as possible in the direction of the letter B on B-trials. If possible, do not allow the dash to fall below the horizontal line after the trial has begun. Instead, move it as far as you can in the direction of the letter A or the letter B. When there is no visual display on the screen, you should rest and wait for the next trial.

We are going to begin by giving you six trials on which you are to move the dash toward the A and six trials on which you are to move the dash toward the B. These trials will be given in an irregular order. However, in addition to these trials we are going to give you some test trials on which the letter A or B will appear, but the dash and horizontal line will not be presented. On test trials the display will look like this when Response A is to be produced (sample) or like this when Response B is to be produced (sample). You should attempt to produce the required response as best you can on test trials, even though the dash will not be available to tell you how successful you have been. Test trials will be given at the beginning of the session and again when the session is finished. You will of course be puzzled as to what you should do on test trials given at the beginning of the session since at this time you will not have had an opportunity to learn about Response A or Response B from the feedback dash. We ask that you simply do the best you can. Our purpose in giving you test trials at the outset is to illustrate what will be required when the session is finished.

Feel free to use any method you wish to produce Response A or Response B, but please do not touch or put pressure on the electrodes we have attached to your body. This will create artifact in our recordings.

To provide extra incentive we are going to pay you bonus money for performing successfully. You could earn up to $2.00 in bonus money if you do well. You will be told how much bonus money you have earned when the session is finished.

If you would like to have these instructions repeated, please tell us now. Otherwise, the experiment will begin in two or three minutes.

APPENDIX C

Open-ended report for INC and DEC subjects in Experiment 1

Name ______________________ Date ______________________

1. Describe what you did to make the dash move in the direction of the A on A-trials:

Rating scales for INC and DEC subjects in Experiment 1

Name________________________ Date________________

3. We would like to have you describe what you did on A-trials using the scales given below. On each scale place an "A" in the box that best describes what you did on A-trials. You may place these letters in the same or different boxes on each scale, as you see fit. Please place an "A" on every scale, even if you find this difficult.

	a great deal						not at all
tense muscles							
relaxed muscles							
slow breathing							
rapid breathing							
moved around in the chair							
kept very still							
calming thoughts							
anxious thoughts							
exciting thoughts							
blank mind							

4. Please rate the degree of success you experienced in moving the dash in the direction of the letter A on A-trials.

I was very successful						I was not successful at all

Open-ended report for INC/DEC subjects in Experiment 1

Name ______________________________ Date ______________________

1. Describe what you did to make the dash move in the direction of the A on A-trials:

2. Describe what you did to make the dash move in the direction of the B on B-trials:

Rating scales for INC/DEC subjects in Experiment 1

Name______________________________ Date____________________

3. We would like to have you describe what you did on A and B-trials using the scales given below. On each scale place an "A" in the box that best describes what you did on A-trials, and, on the same scale place a "B" in the box that best describes what you did on B-trials. You may place these letters in the same or different boxes on each scale, as you see fit. Please place an "A" and a "B" on every scale, even ~~if~~ you find this difficult.

	a great deal						not at all
tense muscles							
relaxed muscles							
slow breathing							
rapid breathing							
moved around in the chair							
kept very still							
calming thoughts							
anxious thoughts							
exciting thoughts							
blank mind							

4. Please rate the degree of success you experienced in moving the dash in the direction of the letter A on A-trials, and the letter B on B-trials. As before, you may place the letters "A" and "B" in the same box or different boxes, as you see fit.

I was very successful						I was not successful at all

APPENDIX D

Instructions for judges in Experiment 1

We are going to ask you to sort the verbal reports of subjects that received visual feedback training for increases and/or decreases in heart rate. Subjects were not informed about the nature of the response being trained or given any suggestions as to how it might be controlled. Our purpose is to determine whether the reports of activities used on increase trials are differentiable from the activities reported on decrease trials.

There are two sets of reports. One is from a group of subjects trained on both increases and decreases. For this group one type of trial was designated by the letter "A" and the other trials type by the letter "B". Some subjects received feedback for increases in heart rate on A-trials and decreases in heart rate on B-trials. For the remainder of the subjects this pattern was reversed. Feedback consisted of a vertical dash that moved toward the trial cue A or B at the top of the television screen when the response was successfully being produced and away from the top of the screen when it was not. Following the completion of training subjects were given a questionnaire that asked them to describe what they did to make the dash move in the direction of the letter A on A-trials and in the direction of the letter B on B-trials. Your task is to read the entire set of reports to get an idea of the range of activities reported and then, on an individual basis, to decide for each subject whether he increased his heart rate on A-trials and decreased it on B-trials, or the reverse. In addition, we would like you to indicate the confidence of your judgment and any reasons you have for your choice.

The second set of reports are from subjects who were trained either to increase or decrease their heart rate. Their procedure was identical except that the response was always designated by the trial cue A. Your task here is to decide whether the subject increased his heart rate on A-trials or decreased his heart rate on A-trials. Confidence judgments and reasons for your choice are again requested.

You are probably wondering how your decisions are to be made. We cannot tell you exactly how to proceed, but we know from previous research that increases in heart rate are likely to be associated with tensing of the muscles or taking deep fast breaths. Decreases in heart rate, on the other hand, tend to be associated with relaxation of the muscles or reduced frequency of breathing. Consequently, you may wish to look for these activities in the subject's report when deciding on training condition. However, we cannot guarantee that this decision rule will work in every case, owing to the possibility of idiosyncratic strategies, so if you see an alternative basis on which to make a decision feel free to use it.

You should note that subjects were assigned to training condition randomly and without restriction. This means the number of subjects in each condition may not be the same. Thus, we suggest you make decisions in each case individually, without attempting to assign each training condition an equal number of times.

APPENDIX E

Instructions for subjects in Experiment 2: FW groups

In this experiment we are going to teach you to control a physiological response that is not usually thought of as being controlled voluntarily. The training procedure will be as follows.

From time to time, a horizontal line and small vertical dash will appear in the center of the television screen in front of you. Above the line and dash will appear the letter A. The display will look like this (sample). The horizontal line represents your level of physiological responding at the start of each trial. Movements of the vertical dash, on the other hand, will be controlled by the physiological response you are to produce. Your task is to move the vertical dash as far as possible in the direction of the letter A. If possible, do not allow the dash to fall below the horizontal line after the trial has begun. Instead, move it as far as you can in the direction of the letter A. In between trials, when there is no visual display on the screen, you should rest and wait for the next trial.

We are going to begin by giving you a series of trials on which you are to move the dash in the direction of the letter A, as we have just explained. However, after this we will give you some more trials on which the letter A will appear, but the dash and horizontal line will not be presented. On these trials, the display will look like this (sample). When this display is presented, you should attempt to produce the physiological response we have taught you to control as best you can, even though the dash will not be available to tell you how successful you have been. This type of trial will not be given until the end of training. However, we want you to know now that we will later ask you to produce the response with the dash removed.

Feel free to use any method you wish to produce the response, but please do not touch or put pressure upon the electrodes we have attached to your body. This will create artifact in our recordings.

To provide extra incentive we are going to pay you bonus money for performing successfully. You could earn as much as $1.00 in bonus money if you do well. You will be told how much money you have earned when the session is finished.

If you would like to have these instructions repeated please tell us now. Otherwise the experiment will begin in 2 or 3 minutes.

Verbal Report 1

The first phase of the experiment has been completed. We are now going to bring in a short questionnaire which we would like to have you fill out. Please do not get out of the chair or remove the electrodes.

Transfer 1

In the next phase of the experiment, we are going to give you some trials on which the letter A will appear, but the dash and horizontal line will not be presented. The display will look like this (sample). On these trials you should attempt to produce the response we have taught you to control as best you can, even though the dash will not be available to tell you how successful you have been. As before, we will pay you bonus money for performing successfully.

If you would like to have these instructions repeated please say so now. Otherwise the experiment will resume shortly.

Transfer 2

The second stage of the experiment has been completed. We are now going to give you some more trials on which the letter A will appear without the dash and horizontal line, just like those you have just received. On these trials, we would like you to produce the response, as you did before. However, we are also going to give you some trials on which the letter B will appear instead of the letter A. The display for these trials will look like this (sample). On B-trials, your task will be to try to make the response go the opposite way. We want you to do this even though the dash will not be available to tell you how successful you have been. In short, on A-trials attempt to produce the response; on B-trials try to make the response go in the other direction. As before, we will pay you bonus money for performing successfully.

Verbal Report 2

This phase of the experiment is now finished. We have one more questionnaire we would like you to fill out. Please do not get up from the chair or remove the electrodes.

Instructions for subjects in Experiment 2: NFW groups

In this experiment we are going to teach you to control a physiological response that is not usually thought of as being controlled voluntarily. The training procedure will be as follows.

From time to time, a horizontal line and small vertical dash will appear in the center of the television screen in front of you. Above the line and dash will appear the letter A. The display will look like this (sample). The horizontal line represents your level of physiological responding at the start of each trial. Movements of the vertical dash, on the other hand, will be controlled by the physiological response you are to produce. Your task is to move the vertical dash as far as possible in the direction of the letter A. If possible, do not allow the dash to fall below the horizontal line after the trial has begun. Instead, move it as far as you can in the direction of the letter A. In between trials, when there is no visual display on the screen, you should rest and wait for the next trial.

Feel free to use any method you wish to produce the response, but please do not touch or put pressure upon the electrodes we have attached to your body. This will create artifact in our recordings.

To provide extra incentive we are going to pay you bonus money for performing successfully. You could earn as much as $1.00 in bonus money if you do well. You will be told how much money you have earned when the session is finished.

If you would like to have these instructions repeated please tell us now. Otherwise the experiment will begin in 2 or 3 minutes.

Verbal Report 1

The first phase of the experiment has been completed. We are now going to bring in a short questionnaire which we would like to have you fill out. Please do not get out of the chair or remove the electrodes.

Transfer 1

In the next phase of the experiment, we are going to give you some trials on which the letter A will appear, but the dash and horizontal line will not be presented. The display will look like this (sample). On these trials you should attempt to produce the response we have taught you to control as best you can, even though the dash will not be available to tell you how successful you have been. As before, we will pay you bonus money for performing successfully.

If you would like to have these instructions repeated please say so now. Otherwise the experiment will resume shortly.

Transfer 2

The second stage of the experiment has been completed. We are now going to give you some more trials on which the letter A will appear without the dash and horizontal line, just like those you have just received. On these trials, we would like you to produce the response, as you did before. However, we are also going to give you some trials on which the letter B will appear instead of the letter A. The display for these trials will look like this (sample). On B-trials, your task will be to try to make the response go the opposite way. We want you to do this even though the dash will not be available to tell you how successful you have been. In short, on A-trials attempt to produce the response; on B-trials try to make the response go in the other direction. As before, we will pay you bonus money for performing successfully.

Verbal Report 2

This phase of the experiment is now finished. We have one more questionnaire we would like you to fill out. Please do not get up from the chair or remove the electrodes.

APPENDIX F

Open-ended report for subjects in Experiment 2 (Verbal Report 1)

Name ______________________________ Date ______________

1. Describe what you did to make the dash move in the direction of the A on A-trials:

2. Please rate the degree of success you experienced in moving the dash in the direction of the letter A on A-trials.

I was very successful						I was not successful at all

Open-ended report for subjects in Experiment 2 (Verbal Report 2)

Name ______________________________ Date ______________

1. Describe what you did to produce the response on A-trials.

2. Describe what you did on B-trials to make the response go in the opposite direction.

Rating scales for subjects in Experiment 2

Name ______________________________ Date ______________________

3. We would like to have you describe what you did on A and B-trials using the scales given below. On each scale place an "A" in the box that best describes what you did on A-trials, and, on the same scale place a "B" in the box that best describes what you did on B-trials. You may place these letters in the same or different boxes on each scale, as you see fit. Please place an "A" and a "B" on every scale, even if you find this difficult.

	a great deal						not at all
anxious thoughts							
calming thoughts							
exciting thoughts							
blank mind							
tensed muscles							
relaxed muscles							
rapid breathing							
slow breathing							
moved around in the chair							
kept very still							

4. What response do you think was being trained?

APPENDIX G

Instructions for judges in Experiment 2

We are going to ask you to sort the verbal reports of subjects that participated in a visceral learning experiment. The response being trained was either an increase or decrease in heart rate. The procedure for the experiment was as follows.

Subjects received a series of feedback trials designated by the presentation of the letter A in the upper right-hand quadrant of a television screen. The feedback consisted of a vertical dash that moved in the direction of the A when the response was successfully produced and away from the letter when it was not. Subjects were divided into two groups. In both groups, subjects were told that their task was to move the dash in the direction of the letter A whenever the feedback display was presented. However, for one group increases in heart rate moved the dash toward the letter A (Increase Group) whereas in the second group decreases in heart rate moved the dash in this direction (Decrease Group). Subjects were not informed about the response being trained or given any suggestions as to how it might be controlled. They were imply instructed to move the dash in the direction of the letter A as best they could using any method they wished.

When feedback training was completed subjects were given a questionnaire that asked them to "describe what you did to make the dash move in the direction of the A". We will refer to this report as <u>Verbal Report #1.</u>

Subjects next received a series of transfer trials on which the letter A appeared without the feedback dash. On these trials they were asked to produce the response as best they could, even though there would be no feedback available to tell them how successful they had been. In addition, they received some trials, designated by the letter B, on which they were asked to "make the response go in the other direction", even though once again there would be no feedback present.

Following the transfer test, subjects were given a second questionnaire which asked them to describe what they did to "produce the response on A-trials" and what they did "on B-trials to make the response go in the other direction". We will refer to this as <u>Verbal Report #2.</u>

Attached to these instructions are transcriptions of Verbal Report #1 and Verbal Report #2 for each subject. Your task is to examine the reports of each subject and decide whether he <u>increased his heart rate on A-trials and decreased it on B-trials, or the reverse.</u> Specifically, we would like you to begin by reading the entire set of protocols; this will give you an idea of the range of activities the subjects reported. Then, we would like to have you do the following:

(1) Examine each subject's verbal reports

(2) On the basis of these reports assign the subject to one training condition (Increase on A and Decrease on B or Increase on B and Decrease on A) using the attached data sheet

(3) Indicate the confidence of your judgment, using the scale provided;

(4) State, if possible, the reason you assigned each subject to a particular training condition.

You are probably wondering how your decisions are to be made. We cannot tell you exactly how to proceed, but we know from previous research that increases in heart rate are likely to be associated with tensing of the muscles or taking deep, fast breaths. Decreases in heart rate, on the other hand, tend to be associated with relaxation of the muscles or reduced frequency of breathing. Consequently you may wish to look for these activities in the subject's report when deciding on training condition. However, we cannot guarantee that this decision rule will work in every case, owing to the possibility of idiosyncratic strategies, so if you see an alternative basis on which to make a decision feel free to use it.

You should note that subjects were assigned to the two training conditions (increase on A and decrease on B, or the reverse) randomly, without restriction. This means the number of subjects in each condition may not be the same. Thus we suggest you make decisions in each case individually, without attempting to assign each training condition an equal number of times.

To repeat, we would like to have you begin by reviewing the entire set of protocols, then, make a decision in each individual case. You may record your answers on the attached data sheet. Please call the experimenter in the next room when you have finished.

APPENDIX H

Presentation and analysis of heart-rate control in Transfer 2 of Experiment 2

The average heart-rate change in beats per minute of each group in Transfer 2 in Experiment 2 is summarized below.

	INC			DEC		
	increase	decrease	bidir.	increase	decrease	bidir.
FW	13.0	-2.3	15.3	4.5	.5	4.0
NFW	10.2	-3.6	13.7	6.3	2.2	4.0
M	11.6	-2.9	14.5	5.4	1.4	4.0

An overall main effect of trial type, $F(2,80) = 17.3$, $p<.05$, indicated that the average increase for all groups combined was higher than the average overall decrease. An interaction between target condition and trial type indicated that this main effect was largely due to the performance of the INC groups: increases in heart rate were found to be significantly greater than decreases in heart rate in the INC condition but not the DEC condition, $F(2,80) = 3.87$, $p<.05$. Furthermore, the average bidirectional difference of the INC condition was significantly higher than that of the DEC condition, $t(42) = 2.17$, $p<.05$. As was found in training and Transfer 1, all comparisons between the FW and NFW conditions were nonsignificant, and decrease performance did not differ from blank trial performance in any group.

APPENDIX I

Within-subject correlations between heart-rate changes and concomitant response changes for subjects in Experiment 2

DIFFERENTIATORS Subject	EMG[a]	MVT[b]	NONDIFFERENTIATORS Subject	EMG	MVT
INC-FW-16	.80*	.83*	INC-FW-1	na[c]	.10
INC-FW-17	.94*	.83*	INC-FW-21	.09	.10
INC-FW-24	.31	.36*	INC-FW-22	.32	.72*
INC-FW-31	.42*	.49*	INC-FW-25	.53*	.60*
INC-FW-32	.65*	.33	INC-FW-29	.05	.15
INC-FW-36	.81*	.75*			
INC-NFW-7	.79*	.74*	INC-NFW-2	.01	.19
INC-NFW-20	.24	.24	INC-NFW-5	.80*	.84*
INC-NFW-27	.84*	.67*	INC-NFW-18	.71*	.51*
INC-NFW-28	.45*	.55*	INC-NFW-19	.38*	.55*
INC-NFW-41	-.18	.01	INC-NFW-35	-.02	.28
			INC-NFW-37	.46*	.58*
DEC-FW-4	.30	.35*	DEC-FW-9	.26	.64*
DEC-FW-40	na	.57*	DEC-FW-10	.04	.45*
			DEC-FW-11	.55*	.39*
			DEC-FW-13	.65*	.56*
			DEC-FW-14	.20	.21
			DEC-FW-15	.16	.41*
			DEC-FW-23	.51*	.43*
			DEC-FW-26	-.21	.56*
			DEC-FW-44	.39*	.68*
DEC-NFW-33	.67*	.34	DEC-NFW-3	.65*	.64*
DEC-NFW-43	.29	.85*	DEC-NFW-6	.68*	.76*
DEC-NFW-42	.39*	.73*	DEC-NFW-8	.37*	.4[illegible]*
			DEC-NFW-12	.36*	.70*
			DEC-NFW-30	.38*	.64*
			DEC-NFW-34	.41*	.24
			DEC-NFW-38	.71*	.60*
			DEC-NFW-39	.62*	.49*
M[d] =	.59*	.59*	M =	.40*	.52*

__Note.__ Underlined values indicate significant differentiation between increase and decrease trials in Transfer 2 as measured by a t-test (one-tailed, unequal variance).

[a]Forearm electromyogram [b]Body movement [c]Not available

[d]r to z transformed

* $p < .05$

APPENDIX J

Instructions for subjects in Experiment 3: NEU groups

In this experiment we are going to teach you to control a physiological response that is not usually thought of as being controlled voluntarily. The training procedure will be as follows.

From time to time, a horizontal line and small vertical dash will appear in the center of the television screen in front of you. Above the line and dash will appear the letter A. The display will look like this (sample). The horizontal line represents your level of physiological responding at the start of each trial. Movements of the vertical dash, on the other hand, will be ~~controlled~~ by the physiological response you are to produce. Your task is to move the vertical dash as far as possible in the direction of the letter A. If possible, do not allow the dash to fall below the horizontal line after the trial has begun. Instead, move it as far as you can in the direction of the letter A. In between trials, when there is no visual display on the screen, you should rest and wait for the next trial.

To provide extra incentive we are going to pay you bonus money for performing successfully. You could earn up to $1.00 in bonus money if you do well. You will be told how much money you have earned when the session is finished.

Feel free to use any method you wish to produce the response, but please do not do anything that will create artifact in our recordings as these are very sensitive. In this regard, it is very important that you remain still, breathe normally, avoid flexing your muscles, and that you do not touch or put pressure on the electrodes.

If you would like to have these instructions repeated please tell us now. Otherwise the experiment will begin in two or three minutes.

Transfer 1

In the next phase of the experiment, we are going to give you some trials on which the letter A will appear, but the dash and horizontal line will not be presented. The display will look like this (sample). On these trials you should attempt to produce the response we have taught you to control as best you can, even though the dash will not be available to tell you how successful you have been. As before, we will pay you bonus money for performing successfully.

If you would like to have these instructions repeated please say so now. Otherwise the experiment will resume shortly.

Transfer 2

The second stage of the experiment has been completed. We are now going to give you some more trials on which the letter A will appear without the dash and horizontal line, just like those you have just received. On these trials, we would like you to produce the response, as you did before. However, we are also going to give you some trials on which the letter B will appear instead of the letter A. The display for thes trials will look like this (sample). On B-trials, your task will be to try to make the response go the opposite way. We want you to do this even though the dash will not be available to tell you how successful you have been. In short, on A-trials attempt to produce the response; on B-trials try to make the response go in the other direction. As before, we will pay you bonus money for performing successfully.

If you would like to have these instructions repeated please say so now. Otherwise the experiment will resume shortly.

Verbal Report

This phase of the experiment is now finished. We are now going to bring in a questionnaire we would like you to fill out. Please do not get up from the chair or remove the electrodes.

Instructions for subjects in Experiment 3: MEN groups

The purpose of this experiment is to test your ability to mentally control the movements of a dash on a television screen. To do this we are going to give you a series of trials in which a horizontal line and small vertical dash will appear in the center of the television screen in front of you. The display will look like this (sample). Your task, simply stated, is to move the vertical dash up as far as possible in the direction of the letter A and to avoid letting it fall below the horizontal line. You are to use mental means to accomplish this. In between trials, when there is no visual display on the screen you should rest and wait for the next trial. In doing this task it is very important that you do not do anything tha will créate artifact in our recordings as they are very sensitive. In this regard, you should remain still, breathe normally, avoid flexing your muscles, and not touch or put pressure on the electrodes.

To provide extra incentive we are going to pay you bonus money for performing successfully. You could earn up to $1.00 in bonus money if you do well. You will be told how much money you have earned when the session is finished.

If you would like to have these instructions repeated please tell us now. Otherwise the experiment will begin in two or three minutes.

Transfer 1

The first phase of the experiment has been completed. In the next phase of the experiment, we are going to give you some trials on which the letter A will appear, but the dash and horizontal line will not be presented. The display will look like this (sample). On these trials you should continue to do whatever you found useful in mentally moving the dash up even though the dash will not be available to tell you how successful you have been. As before, we will pay you bonus money for performing successfully.

If you would like to have thes instructions repeated pleae say so now. Otherwise the experiment will resume shortly.

Transfer 2

The second stage of the experiment has been completed. We are now going to give you some more trials on which the letter A will appear without the dash and horizontal line, just like those you have just received. On these trials, we would like you to again do whatever you found useful in mentally moving the dash up. However, we are also going to give you some trials on which the letter B will appear instead of the letter A. The display for these trials will look like this (sample). On B-trials, your task will be to try to move the dash in the opposite direction. We want you to do this even though the dash will not be available to tell you how successful you have been. In short, on A-trials attempt to move the dash in the direction of the A; on B-trials try and make the dash go in the other direction. As before, we will pay you bonus money for performing successfully.

If you would like to have these instructions repeated please say so now, otherwise the experiment will resume momentarily.

Verbal Report

This phase of the experiment is now finished. We are now going to bring in a questionnaire we would like you to fill out. Please do not get up from the chair or remove the electrodes.

APPENDIX K

Open-ended report for subjects in Experiment 3

Name ______________________ Date ______________________

1. Describe what you did to make the dash move in the direction of the A on A-trials.

2. Describe what you did on B-trials to make the dash go in the opposite direction.

3. Please rate the degree of success you experienced in moving the dash in the direction of the A. Place an "A" in the appropriate box.

I was very successful — I was not successful at all

Rating scales for subjects in Experiment 3

Name ______________________________ Date ________________

4. We would like to have you describe what you did on A and B-trials using the scales given below. On each scale place an "A" in the box that best describes what you did on A-trials, and, on the same scale place a "B" in the box that best describes what you did on B-trials. You may place these letters in the same or different boxes on each scale, as you see fit. Please place an "A" and a "B" on every scale, even if you find this difficult.

	a great deal						not at all
anxious thoughts							
calming thoughts							
exciting thoughts							
blank mind							

5. Even though you may not have used these activities we would like you to indicate how useful you think they may be in making the dash move in the appropriate direction. Or, if you did use them, how useful you found them to be in making the dash move in the appropriate direction. As before, place an "A" and a "B" on each scale corresponding to trial type A and trial type B. Also note the final question.

	very useful						not at all useful
tensing muscles							
relaxing muscles							
rapid breathing							
slow breathing							
moving around in the chair							
keeping very still							

Put a check mark in one of these boxes

none of these activities are useful for either trial type	☐	some of these activities are useful for one or both trial types	☐

APPENDIX L

Instructions for judges in Experiment 3

We are going to ask you to sort the verbal reports of subjects that participated in a visceral learning experiment. The response being trained was either an increase or decrease in heart rate. The procedure for the experiment was as follows.

Subjects received a series of feedback trials designated by the presentation of the letter A in the upper right-hand quadrant of a television screen. The feedback consisted of a vertical dash that moved in the direction of the A when the response was successfully produced and away from the letter when it was not. Subjects were divided into two groups. In both groups, subjects were told that their task was to move the dash in the direction of the letter A whenever the feedback display was presented. However, for one group increases in heart rate moved the dash toward the letter A (Increase Group) whereas in the second group decreases in heart rate moved the dash in this direction (Decrease Group). Subjects were not informed about the response being trained or given any suggestions as to how it might be controlled. They were imply instructed to move the dash in the direction of the letter A as best they could using any method they wished.

Subjects next received a series of transfer trials on which the letter A appeared without the feedback dash. On these trials they were asked to produce the response as best they could, even though there would be no feedback available to tell them how successful they had been. In addition, they received some trials, designated by the letter B, on which they were asked to "make the response go in the other direction", even though once again there would be no feedback present.

Attached to these instructions are transcriptions of each subject's verbal report. Your task is to examine the reports of each subject and decide whether he increased his heart rate on A-trials and decreased it on B-trials, or the reverse. Specifically, we would like you to begin by reading the entire set of protocols; this will give you an idea of the range of activities the subjects reported. Then, we would like to have you do the following:

(1) Examine each subject's verbal reports
(2) On the basis of these reports assign the subject to one training condition (Increase on A and Decrease on B or Increase on B and Decrease on A) using the attached data sheet
(3) Indicate the confidence of your judgment, using the scale provided;
(4) State, if possible, the reason you assigned each subject to a particular training condition.

You are probably wondering how your decisions are to be made. We cannot tell you exactly how to proceed, but we know from previous research that increases in heart rate are likely to be associated with tensing of the muscles or taking deep, fast breaths. Decreases in heart rate, on the other hand, tend to be associated with relaxation of the muscles or reduced frequency of breathing. Consequently you may wish to look for these activities in the subject's report when deciding on training condition. However, we cannot guarantee that this decision rule will work in every case, owing to the possibility of idiosyncratic strategies, so if you see an alternative basis on which to make a decision feel free to use it.

You should note that subjects were assigned to the two training conditions (increase on A and decrease on B, or the reverse) randomly, without restriction. This means the number of subjects in each condition may not be the same. Thus we suggest you make decisions in each case individually, without attempting to assign each training condition an equal number of times.

To repeat, we would like to have you begin by reviewing the entire set of protocols, then, make a decision in each individual case. You may record your answers on the attached data sheet. Please call the experimenter in the next room when you have finished.

APPENDIX M

Presentation and analysis of heart-rate control in Transfer 2 of Experiment 3

The average heart-rate change in beats per minute of each group in Transfer 2 in Experiment 3 is summarized below.

	INC			DEC		
	increase	decrease	bidir.	increase	decrease	bidir.
NEU	6.7	-3.6	10.3	-2.1	-1.3	-.8
MEN	1.1	-.5	1.6	-1.5	0	-1.5
M	3.9	-2.1	6.0	-1.8	-.7	-1.2

Average overall increase performance for all groups combined was found to be significantly higher than average overall decrease performance - $F(1,48) = 4.15$, $p<.05$. An interaction between target condition and trial type, $F(1,48) = 8.99$, $p<.05$, indicated that this effect was in large part due to the performance of the INC condition: a Tukey test determined that increases in heart rate in the INC condition were significantly greater than the increases in the DEC condition. An additional interaction between instructional condition and trial type, $F(1,48) = 3.99$, $p<.05$, indicated that significant differentiation between increases and decreases was confined to the NEU condition alone. A three way interaction between target condition, instructional condition and trial type did not achieve significance. A comparison of bidirectional scores showed that the bidirectional performance of the INC-NEU group was significantly higher than the INC-MEN, $t(24) = 2.05$, $p<.05$ (one-tailed), and the DEC-NEU groups, $t(24) = 2.98$, $p<.05$. In addition, the overall bidirectional scores of subjects in the INC condition were significantly higher than that of the DEC condition, $t(50) = 2.90$, $p<.05$; and the bidirectional performance of the NEU condition was superior to that of the MEN condition, $t(50) = 1.81$, $p<.05$.

APPENDIX N

Within-subject correlations between heart-rate changes and concomitant response changes for subjects in Experiment 3

DIFFERENTIATORS

Subject	EMG[a]	MVT[b]	RF[c]	RV[d]
INC-NEU-32	-.24	.69*	-.43*	.07
INC-NEU-39	.71*	.74*	-.28	.33
INC-NEU-47	.37*	.85*	-.57*	0
INC-MEN-19	--	.43*	-.18	.23
INC-MEN-35	--	.11	-.48*	-.07
INC-MEN-50	--	.27	na	na
INC-MEN-57	--	.04	-.36*	-.04
DEC-NEU-45	.42*	.46*	-.43*	.07
M^{e} =	.35*	.51*	-.40*	.09

NONDIFFERENTIATORS

Subject	EMG	MVT	RF	RV
INC-NEU-1	.24	.60*	-.39*	.43
INC-NEU-3	-.06	.31	.47*	.66*
INC-NEU-7	.28	.36*	-.50*	.02
INC-NEU-13	.04	.64*	na	na
INC-NEU-22	.19	.38*	-.05	.55*
INC-NEU-27	-.26	.57*	-.16	.35*
INC-NEU-43	.19	.32	na	na
INC-NEU-44	.55*	.63*	na	na
INC-NEU-53	.30	.19	.31	-.16
INC-NEU-59	.50*	.66*	.15	.53*
INC-MEN-10	--	.68*	.57*	.40*
INC-MEN-11	--	.61*	.08	.75*
INC-MEN-15	--	.61*	-.04	.43*
INC-MEN-28	--	-.20	.13	-.14
INC-MEN-31	--	.31	-.39	.65*
INC-MEN-37	--	.36*	-.05	.41*
INC-MEN-38	--	.36*	-.27	.36
INC-MEN-56	--	.29	-.12	0
INC-MEN-58	--	.59*	-.10	.56*
DEC-NEU-2	.35*	.35*	-.28	.14
DEC-NEU-6	.32	.22	-.31	-.02
DEC-NEU-14	.43*	.53*	.29	.52*
DEC-NEU-17	.84*	.83*	-.09	.57*
DEC-NEU-23	.19	.01	na	na
DEC-NEU-33	.25	.15	-.07	.10
DEC-NEU-36	.29	.79*	-.09	.55*
DEC-NEU-46	.12	.25	-.06	.52*
DEC-NEU-48	.22	.47*	.33	.61*
DEC-NEU-51	.15	.62*	-.03	.48*
DEC-NEU-54	-.35*	.69*	-.28	.49*
DEC-NEU-55	.29	.58*	-.19	.33
DEC-MEN-8	--	.80*	-.73*	.68*
DEC-MEN-12	--	.23	-.32	-.36*
DEC-MEN-16	--	.06	na	na
DEC-MEN-18	--	.65*	-.20	.70*
DEC-MEN-21	--	.42*	.38*	.32
DEC-MEN-24	--	.71*	-.64*	.12
DEC-MEN-29	--	na	.26	-.25
DEC-MEN-30	--	.56*	-.34*	.13
DEC-MEN-34	--	.68*	-.42*	.30
DEC-MEN-40	--	.31	.02	.44*
DEC-MEN-41	--	.08	.03	.09
DEC-MEN-42	--	.45*	-.22	.28
DEC-MEN-52	--	-.01	na	na
M =	.25	.47*	-.10	.35*

Note. Underlined values indicate significant differentiation in the appropriate direction during Transfer 2.

[a] Forearm electromyogram [b] Body movement [c] Respiratory frequency
[d] Respiratory volume [e] r to z transformed

* $p < .05$

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