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THE UTILITY OF PROLONGED RESPIRATORY EXHALATION FOR REDUCING PHYSIOLOGICAL AND PSYCHOLOGICAL AROUSAL IN NON-THREATENING AND THREATENING SITUATIONS*

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Abstract—To determine whether slowing and altering the respiratory pattern is an effective means for reducing physiological and psychological arousal, subjects participated in one of three treatment conditions in which they reduced their respiration rate to 6 cpm and either inhaled quickly and exhaled slowly, inhaled slowly and exhaled quickly, or spent equal amounts of time inhaling and exhaling. Other subjects participated in a distraction control condition or in a no-treatment control condition. Arousal was measured during a practice period, a threat (electrical shocks) anticipation period, and a threat confrontation period. The results indicated that the breathing manipulations were not effective in reducing arousal during the practice period, but that inhaling quickly and exhaling slowly was consistently effective for reducing physiological (skin resistance) and psychological (subjective cognitive) arousal during the anticipation and confrontation periods.

A CONSIDERABLE amount of research has been devoted to studying techniques by which persons could control their physiological and psychological arousal in non-threatening and threatening situations. For example, attention has been focused on cognitive strategies, meditation, biofeedback, and relaxation exercises. One technique for reducing arousal which was examined recently involves the voluntary alteration of respiration rate [1–3]. Most importantly, it was reported that subjects who reduced their respiration rate to one-half the normal rate evidenced reliable reductions in both their physiological arousal (skin resistance) and psychological arousal (self-reports) relative to subjects who did not reduce their respiration rates [1].

Although it seems clear that by controlling their respiration rate subjects can reduce their arousal, it may be that by also controlling the phases of their respiratory cycles (inhalation and exhalation) subjects may be able to achieve greater and more pervasive reductions in arousal. Specifically, slowed respiration in combination with *prolonged exhalation* may be particularly effective for reducing arousal. This maneuver for reducing arousal has been suggested by many yogi masters [4–6] but it has not yet been subjected to an experimental test. Related to this possibility, it is interesting to note that when under stress subjects show a spontaneous prolongation of the exhalation phase of the respiratory cycle [7], and it may be that the extension of that phase of the cycle is part of a protective general reaction to stress.

The present experiment was conducted to test the possibility that altering the phases of the respiratory cycle would reduce subjects' physiological and psychological arousal in non-threatening and threatening situations. The subjects in three conditions of this experiment reduced their respiration rate to 6 cpm and used different inhalation/exhalation patterns (fast/slow, slow/fast, equal) while in a non-threatening period, while anticipating a forthcoming shock period, and while

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confronting the possibility of shocks during the shock period. To control for the possible influence of the distraction associated with the respiration manipulation, the subjects in a distraction control condition did not attempt to manipulate their respiration but instead participated in a vigilance/distraction task. To obtain a measure of the degree to which subjects would become aroused in the absence of the respiration and distraction manipulations, subjects in a no-treatment/threat condition were simply asked to sit quietly during the non-threatening and threatening periods of the experiment. Finally, to obtain baseline measures of arousal that were independent of the manipulation of respiration, distraction, and threat, subjects in a no-treatment/no-threat condition were asked to sit quietly and were told that the stimulation they would receive would come from a red light (rather than shocks). Arousal was measured throughout the experiment in terms of skin resistance, heart rate, systolic blood pressure, diastolic blood pressure, subjective (self-reported) cognitive arousal, and subjective (self-reported) somatic arousal.

METHOD

Subjects

Thirty-nine males and 21 females from General Psychology classes at the University of Kansas volunteered to participate in the experiment to fulfill part of the research participation requirement of their psychology class. The subjects were randomly assigned in equal numbers to the six conditions of the experiment.

Procedures

After being given a brief tour of the laboratory and signing an informed consent statement, each subject was taken into a research cubicle, seated at a desk, and had the various physiological recording devices attached. Specifically, a finger pulse transducer was attached to the second finger of the subject's non-dominant hand, skin resistance electrodes were attached to the distal phalanx of the first and third fingers of that hand, and plate electrodes were placed on either side of the subject's chest and over the sternum, and a blood pressure cuff with a built in microphone was wrapped around the subject's dominant arm. (A concentric circle shock electrode was attached to the ventral dominant forearm of subjects in the threat condition during that phase of the experiment. Silver/silver chloride plate electrodes were used in conjunction with an impedence pneumograph (type 7212) and a 10-Hz filter to measure respiration. A type 7173 transducer coupler was used in conjunction with the finger pulse transducer and a 10-kHz filter. Skin resistance was recorded using a type 7175 GSR coupler and 10-Hz filter. Subject skin resistance was measured in kOHMS and standardized at 100 OmV/CM. Signal amplification was obtained using type 7070 channel amplifiers. All of the physiological recording equipment used in this experiment was produced by Narco Bio-Systems.) After the equipment was attached, the subject was told that the instructions for the experiment would be provided by a tape recording, and then the experimenter left the room and went to the control room where he started the tape recorder and the polygraph.

Each subject was told that the first phase of the experiment consisted of a 5-min rest period which would allow the subject to become accustomed to the situation and allow the experimenter to calibrate the equipment. The subject was then allowed to sit quietly for the 5-min adaptation period.

At the end of the 5-min adaptation period, each subject was asked to use a self-report inventory to indicate how he/she was feeling at that time.[1] The inventory contained 21 item-stems such as, "I feel nervous" and "I feel physically shakey," and it could be scored to yield a measure of subjective cognitive arousal and a measure of subjective somatic arousal.[2] The subject used 5-point scales to indicate the degree to which each statement was descriptive of him/her at that time. After that form was completed, the respiration and distraction manipulations were introduced.

[1]Holmes DS. The cognitive and somatic components of anxiety. Unpublished manuscript, University of Kansas, 1982.

[2]The scales measuring cognitive and somatic arousal were derived from a series of factor analytic studies. The two separate scales were used rather than one general measure because other investigators have pointed out the importance of considering the components of arousal [14].

Fast/slow, slow/fast, and equal conditions. Each subject who had been assigned to the fast/slow, slow/fast or equal conditions was asked to look at the clock that was directly in front of him/her on the desk. A frame was placed over the face of the clock such that each 10-sec segment of the circumference of the clock's face, i.e. between 12 and 2, 2 and 4, etc., was divided into one blue portion and one brown portion. When a subject was being run in the fast/slow condition, the blue portion covered a 2-sec span and the brown portion covered an 8-sec span. When a subject was being run in the slow/fast condition, the blue portion covered an 8-sec span and the brown portion covered a 2-sec span. When a subject was being run in the equal condition, the blue and the brown portions each covered 5-sec spans. Each subject was then told that the experiment dealt with the types of physiological responses that are associated with different respiratory patterns and that his/her task in the experiment was to breathe in such a way that he/she inhaled steadily while the secondhand on the clock was sweeping through the blue portion and exhaled steadily while the secondhand was sweeping through the brown portion, e.g. in the fast/slow condition the subject was to inhale deeply and quickly during the 2-sec period, and then exhale slowly and steadily during the 8-sec period. The subject was told that he/she would receive additional instructions after a 5-min practice period, but that he/she should continue breathing in accordance with the secondhand on the clock until the end of the experiment.

Distraction condition. Each subject who had been assigned to the distraction condition was asked to look at the clock. When a subject was being run in this condition, the frame on the clock was the one in which the blue and brown portions each covered 5-sec spans. The subject was then told that the experiment dealt with the physiological responses that are associated with vigilance, and that his/her task was to watch the secondhand and indicate by pushing a button on the desk each time the secondhand entered a blue portion of the frame. The subject was told that he/she would receive additional instructions after a 5-min practice period, but that he/she should continue monitoring the secondhand and pushing the button when appropriate until the end of the experiment.

No-treatment condition. Each subject in this condition was told that the experiment dealt with the physiological responses that are associated with sitting quietly, and the subject was told to simply continue sitting quietly as he/she had been doing and that he/she would receive additional instructions later.

After the subject had been successfully practising the respiration maneuver or the vigilance task or had been sitting quietly for 5-min, the subject was asked to respond to a 21-item self-report inventory like the one that had been used in the initial phase of the experiment. However, because most of the subjects were now watching the clock (either to pace their respiration or as a distraction), they could not read and fill out the form as they had before, and therefore the statements on the inventory were read to the subject and he/she indicated the level of agreement for each statement by briefly raising one, two, three, four, or five fingers. The experimenter observed the subjects' responses through a one-way window behind the subject and recorded the responses. When that was completed, the threat manipulation was introduced.

Threat condition. The subjects in all of the conditions except the no-treatment/no-threat condition were exposed to the threat. Specifically, each of those subjects were told that in the next phase of the experiment their response to stimulation would be studied, and that the stimulation would come in the form of a series of painful electric shocks. The subject was assured that although most subjects found the shocks to be painful, the shocks were not harmful or dangerous. The subject was then informed that a 90-sec "wait period" would precede a 90-sec "stimulation" period, and that the wait period would be signaled by a green light mounted next to the clock and that the stimulation period would be signaled by a red light mounted next to the clock. Finally, the subject was told that the shocks would be distributed randomly throughout the stimulation period and that he/she would receive four shocks. Following that, the wait and shock periods were announced and the corresponding lights came on and went off as appropriate. It should be noted, however, that no shocks were actually administered.

No-threat condition. The instructions and procedures for each subject in the no-threat condition were like those of the subjects in the threat conditions except that the subject was told that the experiment dealt with responses to simple visual stimulation and that the stimulation would be provided by the red signal light. Electrical shocks were never mentioned in the no-threat condition.

At the conclusion of the stimulation period, the subject was informed that the experiment was over (subjects in the respiration and distraction conditions could therefore cease their tasks), the subject was asked to complete a 21-item self-report inventory like the one used earlier except that on this one the subject was asked to complete it in terms of how he/she felt during the confrontation period, the recording devices were removed, and the subject was completely debriefed.

Check on respiration manipulation

The records of subjects' respiration patterns were shown to two independent judges who were each asked to identify the conditions in which the subjects had served (fast/slow, slow/fast, equal, or one of the conditions which did not involve a slowed or altered pattern). The judges agreed and correctly identified conditions for 53 subjects. The 7 subjects for whom there was disagreement and misidentification (3 from the fast/slow condition; 3 from the slow/fast condition; and 1 from the equal condition) were replaced by additional subjects.

Scoring of data

Physiological measures were obtained during four intervals. The first interval was the last 90 sec of the initial period, and the scores obtained during that interval were used as the measures of the subjects' initial levels of arousal. The second interval was the last 90 sec of the practice period, whereas the third and fourth intervals were the 90 sec of the period and the last 90 sec of the confrontation period.

Heart rate was determined by counting the number of heart beats in the first 30 sec of each interval. Skin resistance was assessed by determining the highest resistance, i.e. the point reflecting the lowest level of arousal, in the first 30 sec of the intial and practice intervals, and by determining the lowest resistance, i.e. the point reflecting the highest level of arousal, in the anticipation and confrontation intervals. Systolic and diastolic blood pressure were measured during the last minute of the initial, practice, anticipation, and confrontation periods. Respiration was recorded throughout the experiment both to check on the breathing manipulation and to check for artifact. In this way any cardio-respiratory reflexes such as coughing could be detected and the data handled appropriately.

RESULTS

Practice period

One-way analyses of covariance were conducted to compare the scores of the subjects in the fast/slow, slow/fast, equal, distraction, and no-treatment conditions on each of the physiological and psychological variables.[3] In each of those analyses, the scores for that variable from the initial period were used as the covariate.[4] If an analysis revealed a reliable difference among the condition means, the condition means for that variable are presented in Table 1. Note that in Table 1 *any means that are underlined by the same line are not reliably different* at the 0.05 level, whereas *any means that are not underlined by the same line are reliably different* at beyond the 0.05 level.[5]

Physiological measures. The analysis conducted on the skin resistance scores revealed a reliable difference among the conditions, $F\ (4,54) = 5.31$, $p = 0.001$. Inspection of the means in Table I indicates that the subjects who simply sat quietly (no-treatment) or simply watched the clock (distraction) evidenced reliably lower levels of arousal than the subjects who practiced the respiration maneuvers (fast/slow, slow/fast, equal), and that all of the subjects who practiced the respiration maneuvers evidenced comparable levels of arousal. It appears then that during the practice period the effort involved in accomplishing the respiratory maneuvers heightened subjects arousal as measured by skin resistance. The analyses of covariance that were conducted on the heart rate, systolic blood pressure, and diastolic blood pressure data did not reveal any reliable difference among the conditions.

Psychological measures. The analysis conducted on the subjective cognitive arousal scores revealed a reliable difference among the conditions, $F\ (4,54) = 2.76$, $p = 0.036$. Inspection of the means presented in Table I indicates that the subjects in the distraction condition reported higher cognitive arousal than did the subjects in

[3]It might be noted that for the analyses of data from the practice period, the subjects in the no-treatment/threat and no-treatment/no-threat conditions were combined to form one no-treatment condition. That was done because the threat manipulation was not introduced until after the practice period, and therefore until that point the subjects in the no-treatment/threat and no-treatment/no-threat conditions had been treated in the same way.

[4]Analyses of covariance were used to eliminate any possible influence of the law of initial values [13, 15]. Such corrections are necessary even when there are not reliable initial differences between conditions because it has been demonstrated that even unreliable initial differences can create or obscure subsequent differences, e.g. [12].

[5]The error term and degrees of freedom used in making all of the paired comparisons reported in this article were obtained from the relevant overall analyses of variance, thus providing a more sensitive measure of error variance [16].

any of the other conditions and that there were not reliable differences among any of those latter conditions. The analysis conducted on the subjective somatic arousal scores did not reveal a reliable difference among the conditions. It appears then that during the practice period the vigilance required by the distraction task served to increase subjects' subjective cognitive arousal but not their subjective somatic arousal, and that none of the respiratory strategies influenced subjective arousal.

Anticipation period

Physiological measures. A series of 6 (fast/slow, slow/fast, equal, distraction, no-treatment/threat, no-treatment/no-threat) by 2 (anticipation period, confrontation period) analyses of covariance with repeated measures were conducted to compare the subjects on the various physiological measures. In each of those analyses, the initial period scores for the variable in question were used as the covariate. The findings of those analyses which are related to the anticipation period will be reported in this section and the findings which are related to the confrontation period will be reported in the following section. If an analysis revealed a reliable difference among the condition means, the condition means for that variable are presented in Table I.

TABLE I

Practice period means					
Skin resistance					
No-threat	Distract	Fast/slow	Slow/fast	Equal	
280.24	178.62	156.31	150.16	115.29	
Subjective cognitive arousal					
Equal	No-threat	Slow/fast	Fast/slow	Distract	
7.35	7.75	7.89	8.09	10.05	
Anticipation period means					
Skin resistance					
Equal	No-threat	Fast/slow	Slow/fast	Distract	Threat
117.19	108.48	92.01	80.04	76.21	62.95
Confrontation period means					
Skin resistance					
No-threat	Fast/slow	Equal	Slow/fast	Distract	Threat
112.78	96.41	82.39	79.64	74.71	68.35
Subjective cognitive arousal					
No-threat	Fast/slow	Slow/fast	Distract	Equal	Threat
7.56	10.82	11.59	14.34	14.86	16.00
Subjective somatic arousal					
No-threat	Distract	Fast/slow	Slow/fast	Equal	Threat
10.28	14.62	15.35	17.29	18.75	19.19

Notes: Any means that are underlined by the same line are not reliably different at the 0.05 level, whereas any means that are not underlined by the same line are reliably different at beyond the 0.05 level. Higher skin resistance scores reflect lower arousal.

The analysis which was conducted on the skin resistance scores revealed a reliable difference among the conditions, $F\ (5,53) = 3.41$ $p = 0.009$. A series of paired comparisons conducted on the skin resistance data for the anticipation period revealed four important findings: First, the subjects in the no-treatment/threat

condition were reliably more aroused than the subjects in the no-treatment/no-threat condition, thus indicating that the threat manipulation was successful during the anticipation period.

Second, the subjects in both the equal and fast/slow conditions evidenced reliably lower arousal than subjects in the no-treatment/threat condition and did not differ reliably in arousal from subjects in the no-treatment/no-threat condition, thus indicating that both the equal and the fast/slow strategies were effective for reducing arousal while subjects were anticipating a threat.

Third, it was found that the subjects in the slow/fast and distraction conditions evidenced arousal levels which were not reliably different from subjects in the no-treatment/threat condition but which were reliably higher than those of subjects in the no-treatment/no-threat condition. Those findings indicate that the slow/fast and distraction strategies were not effective for controlling arousal while anticipating a threat.

Fourth, it should be noted that although both the equal and fast/slow strategies were found to be reliably effective for reducing arousal, only the equal strategy was reliably more effective than the other strategies.

The analyses conducted on the heart rate, systolic blood pressure, and diastolic blood pressure data did not reveal reliable differences among the conditions or reliable conditions by periods interactions.

From these results it appears that the stress effects were limited to the skin resistance measure and that both the equal respiration and fast/slow respiration strategies were effective for reducing arousal, although only the equal strategy was reliably more effective than the other strategies.

Psychological measures. Measures of subjective cognitive and subjective somatic arousal were not obtained for the anticipation period in order that the 90-sec confrontation period might follow immediately.

Confrontation period

Physiological measures. The findings related to the confrontation period which were generated by the 6 (conditions) by 2 (anticipation period, confrontation period) analyses of covariance which were described in the preceding section provided the basis for the results to be discussed in this section.

Because the analysis of the skin resistance data had revealed a reliable overall difference among the conditions, a series of paired comparisons were conducted to identify the differences which were specific to the confrontation period. Those analyses revealed four important findings: first, the subjects in the no-treatment/threat condition were reliably more aroused than the subjects in the no-treatment/no-threat condition, thus indicating that the threat manipulation was successful during the confrontation period.

Second, the subjects in the fast/slow condition were reliably less aroused than the subjects in the no-treatment/threat condition and did not differ reliably in arousal from the subjects in the no-treatment/no-threat condition. Those findings indicated that the fast/slow breathing manipulation was effective for reducing arousal while subjects were confronting a threat.

Third, it was found that the subjects in the equal, slow/fast, and distraction conditions were reliably more aroused than the subjects in the no-treatment/no-

threat condition and did not differ reliably in arousal from the subjects in the no-treatment/threat condition. Those findings indicate that the equal, slow/fast, and distraction manipulations were not effective for reducing arousal while subjects were confronting a threat.

Fourth, it should be noted that differences between the arousal levels of the subjects in the fast/slow condition and the subjects in the other coping conditions were not reliable or only approached reliability. Those findings indicate that although the fast/slow maneuver was reliably effective for reducing arousal and the other maneuvers were not, the fast/slow maneuver was not reliably more effective than the others for reducing arousal while confronting a threat.

Psychological measures. The subjective cognitive arousal scores from the six conditions were analysed with a one-way analysis of covariance in which the initial cognitive arousal scores were the covariates. That analysis revealed a reliable difference among the means, $F(5,53) = 3.22$, $p = 0.013$. Inspection of the data in Table I indicates that the subjects in the no-treatment/threat condition reported higher cognitive arousal than the subjects in the no-treatment/no-threat condition, thus indicating that the threat manipulation influenced cognitive arousal during the confrontation period. Second, the subjects in the fast/slow condition reported reliably less arousal than the subjects in the no-treatment/threat condition and did not report arousal that was reliably different from that reported by the subjects in the no-treatment/no-threat condition, thus indicating that the fast/slow maneuver was effective for reducing subjective cognitive arousal. It is also relevant to note that the other strategies were not effective for reliably reducing arousal and were or closely approached (fast/slow vs slow/fast, $p = 0.10$) being reliably less effective than the fast/slow maneuver.

The analysis conducted on the subjective somatic arousal data for the confrontation period also revealed a reliable difference among the means, $F(4,53) = 5.30$, $p < 0.001$. Inspection of the data in Table I indicates that none of the strategies were effective in reducing subjective somatic arousal to the level evidenced by subjects in the no-treatment/no-threat condition, and that only the subjects in the distraction condition evidenced reliably lower levels of arousal than the subjects in the no-treatment/threat condition. It might be noted, however, that the difference between the no-treatment/threat and fast/slow conditions closely approached reliability ($p = 0.06$).

DISCUSSION

The findings associated with the practice phase of this experiment indicated that the general slowing of respiration resulted in an increase in arousal as measured by skin resistance and that the distraction manipulation caused an increase in self-reported cognitive arousal. Those differences can probably be attributed to the effort (physical and cognitive) associated with the tasks in the various conditions. There were no differences among the conditions on the measures of heart rate, systolic blood pressure, or self-reported somatic arousal. The general absence of physiological differences between the resting subjects (no-treatment) and the subjects who reduced their respiration rates (as is done in some forms of meditation) is consistent with the absence of differences reported in experiments comparing the

arousal levels of subjects who are simply resting with those of subjects who are meditating [8–11].

More interesting and potentially more important findings were generated in the anticipation and confrontation phases of the experiment during which the physiological effects of the threat were apparent with the skin resistance measure. In the anticipation phase, both the equal breathing and the fast/slow breathing maneuvers were effective for reducing physiological arousal. In the confrontation period only the fast/slow breathing maneuver was effective for reducing physiological arousal. With regard to psychological arousal during the confrontation period, it was found that the fast/slow maneuver was effective for reducing subjective cognitive arousal, and tended to be effective for reducing subjective somatic arousal.

Four things should be noted about the pattern of the results in the anticipation and confrontation phases. First, it should be recognized that the fast/slow maneuver was effective in reducing arousal in each case, i.e. there were reliable effects on physiological arousal during anticipation, on physiological arousal during confrontation, on subjective cognitive arousal during confrontation, and a near reliable effect on subjective somatic arousal during confrontation, and in only one case was one of the other respiratory maneuvers effective (the equal maneuver reduced physiological arousal during anticipation). The consistency of the effects across situations and across measures is striking. Second, it should be noted that the equal maneuver was effective for reducing physiological arousal in the anticipation phase but not in the confrontation phase. Interestingly, that is exactly the pattern that was reported in an earlier investigation in which the effects of slowed respiration (with equal inhalation and exhalation) were examined [1]. That consistency in findings across experiments adds to our confidence in the present findings. Third, it is important to point out that although the fast/slow respiratory maneuver was reliably effective in reducing arousal and that the other maneuvers were not, the fast/slow procedure was not reliably more effective than the other procedures. Fourth and finally it should be noted that among the physiological measures of arousal the the effects of the threat (and hence the effects of the coping strategies) were limited to the measure of skin resistance. That was probably the case because the threat was not particularly severe and hence would not impact upon the generally more robust measures of heart rate and blood pressure.

In summary, the results of this investigation provide consistent evidence that rapid inhalation followed by slow exhalation in an overall pattern of reduced respiration rate can be an effective technique for reducing physiological and psychological arousal when anticipating and confronting a threat. This technique has been advocated by yogi masters for many years, but this appears to be the first controlled test of its utility.

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