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Robert M. Stern, et al

Indiana University
Bloomington, Indiana

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Robert M. Stern and Carol Anschel

Pennsylvania State University

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Deep Inspirations as Stimuli for Responses of the Autonomic Nervous System [1]

Robert M. Stern and Carol Anschel

Pennsylvania State University

Abstract

The effects of four types of deep breaths on the latency, the magnitude and the duration of finger volume pulse, heart rate and galvanic skin responses were studied in a quasi-learning situation. The respiratory stimuli were normal inspirations, three times deeper than normal, six times deeper and fast, and six times deeper and slow. Twenty Ss took each type of deep breath in random order six times in response to specific lights. Graphs and statistical tests are presented summarizing the above relationships and two unexpected findings are discussed.

DESCRIPTORS: Inspirations, Respiration, GSR, Heart Rate, Finger Volume Pulse.

The purpose of this study was to obtain empirical data which would show the effects of four types of breaths on the latency, magnitude and duration of vasomotor, heart rate and galvanic skin responses (GSRs) in a quasi-learning situation.

Engel and Chism (1967) have recently presented data dealing with the relationship of breathing rate to heart rate and finger pulse volume. Other than this report and a preliminary experiment in a study of cardiac conditioning reported by Westcott and Huttenlocher (1961), all other work in this area has been oriented towards determining physiological mechanisms and has usually dealt with extreme changes in respiration. The mechanisms involved in the reflexive action of deep inspirations on the vasomotor response have been discussed by numerous investigators (Stewart, 1911; Bolton, Carmichael and Stürup, 1936; Bolton, Carmichael and Williams, 1936; Mulinos and Shulman, 1939; Gilliatt, 1948; Brown, 1953; Ackner, 1956; Tang, Maire and Amassian, 1957; Widdicombe, 1964; Sharpey-Schafer, 1965).

The effects of respiratory maneuvers on heart rate, sinus arrhythmia, were first described by de Cyon and Ludwig in 1847 (see Scher, 1965). More recent discussions of this relationship can be found in the writings of Schneider (1930), Manzotti (1958), Clynes (1960), Guyton (1961) and Brener (1967). Studies dealing with the relationship of respiration to the GSR are more difficult to find (Wells, 1911 as cited in Brown, 1953; Carmichael, Honeyman, Kolb and Stewart, 1941; Kuno, 1956). Whereas, it is well documented that a deep inspiration causes vasoconstriction in the extremities, an increase followed by a decrease in heart rate, and a GSR, the mechanisms involved are still not well understood. The following five factors are vaguely referred to in varying degrees of importance by different authors: (1) "spill-over" of impulses in the medulla from the respiratory center to the vasomotor center, (2) stretch receptors in the lungs, (3) changes in pressure in the thoracic cavity, (4) baroreceptors and (5) chemoreceptors.

Of greater concern to the present investigators was the "negative" aspect of respiration, i.e., confounding of deep breaths in studies involving the responsiveness of the autonomic nervous system (ANS). K. Smith (1954) was the first to point out the importance of controlling respiration in classical conditioning studies of the ANS. Wescott and Huttenlocher (1961), R.W. Smith (1963), Wood and Obrist (1964) and Black (1965) among others have called attention to the effects of breathing in classical conditioning studies of heart rate. The confounding effects of deep inspirations have also been recognized in operant conditioning studies of heart rate (Shearn, 1962; Hnatiow and Lang, 1965; Brener and Hothersall, 1966;

Trowill, 1967; Miller and DiCara, 1967), and spontaneous GSRs (Stern, Boles and Dionis, 1966; Van Twyver and Kimmel, 1966). Royer (1966) has recently discussed the relationship of the respiratory reflex to the orienting reflex.

It was expected that the present study would shed light on the methodological problem of deciding (a) how much and (b) for how long an ANS response which occurs concomitantly with a deep inspiration should be attributed to a respiratory reflex rather than the stimulus being manipulated.

Method

Subjects. Twenty male undergraduates at Indiana University were used in this study. None suffered from any respiratory, cardiac or circulatory disturbances; all were paid for their services.

Apparatus and Procedure. When S arrived for a session, he was taken to an electrically shielded experimental room where he was given the following instructions to read:

> We are interested in studying the interaction among several physiological measures. This is the reason we are putting so many electrodes on you. In order to assess the interaction correctly we have designed a simple task which requires your full attention and co-operation. Before you is a board with seven lights mounted on it. Each will be a signal for you to respond in a specific manner.
>
> Upper left---------While light is on inhale slightly deeper than you normally do, with mouth closed and at a

normal speed. Do this once, then continue breathing normally.

Upper middle------While light is on inhale as deeply and as slowly as you can, with mouth closed. Do this once, then continue breathing normally.

Upper right-------While light is on inhale as deeply and quickly as you can, with mouth closed. Do this once, then continue breathing normally.

Do not hold your breath at the end of each inspiration. Exhale normally.

Middle------------Do not respond to this light.

Bottom left-------While light is on blink both eyes with normal intensity and speed. Do this once, then continue blinking normally.

Bottom middle-----While light is on blink both eyes as slowly as you can, pressing your eyelids together tightly before opening eyes. Do this once, then continue blinking normally.

Bottom right------While light is on blink both eyes as quickly as you can, pressing your eyelids together tightly before opening eyes. Do this once, then continue blinking normally.

The physiological responses to the last three lights were not analyzed; no measure of eye blink was obtained. The lights themselves were included to disguise the true nature of the study. With E still in the room, each light was lit in turn and S was asked to respond appropriately. When necessary, this was repeated until S made all correct responses. During the actual experimental session, each light was presented six times, all 42 lights appearing in a random order. The duration of each light was 2 sec.; the selection of each particular light was done manually. The intralight-interval varied from 25 sec. to 55 sec. and was controlled by a tape timer. The onset of a light was accompanied by a deflection of the marker pen on each of the physiological recorders.

Physiological Recording. Respiration, finger pulse volume, and heart rate were simultaneously recorded on an Offner type R Dynograph. The transducer used for recording respiration was a mercury-filled rubber tube which was placed around S's chest. An optical plethysmograph transducer was attached to S's right index finger to detect vasomotor activity. Capacitance coupling was used to eliminate DC shift, the measure presented in this paper being the height of individual AC signals (pulse volume). EKG was recorded using standard lead II, the signal being conditioned by an Offner cardio-tachometer. Skin resistance was recorded on a Stoelting 100 mv servo-recorder using an imposed constant current of 30 μ amps from a self-resetting GSR unit designed and constructed at Indiana University. Electrodes were zinc, manganese dioxide and sodium chloride. One circular electrode 1 in. in diameter was applied to the left palm and the other attached over a saline soaked piece of sponge rubber 1 x 2 x 6 in. on the left arm.

Results

The relative amplitude of breaths actually taken by the 20 Ss to those lights which required a respiratory response is shown in Figure 1. As can be seen in this figure, the group mean response to the light which called

Insert Fig. 1 about here

for a breath slightly deeper than normal produced a pen deflection approximately three times that produced by a normal breath; the mean response to both the light that signaled a deep and fast inspiration and deep and slow was about six times as great as normal. (The necessary calibrations for the respiration transducer used were not obtained; therefore, the depths of breaths cannot be expressed in terms of volumetric changes in respiration.) Table 1 summarizes the results of *t* tests that were used to compare the peak amplitudes for respiration as well as the effects of

Insert Table 1 about here

respiration on other ANS responses. As can be seen in this table, the differences in depth of inspiration depicted in Fig. 1, i.e., normal vs. slightly deeper, slightly deeper vs. deep and fast, slightly deeper vs. deep and slow, are all significant. It should be noted that for these and all following *t* tests, each *S*'s peak response was used rather than each *S*'s response at a certain place in time. Mean latencies are depicted in terms of seconds from onset of the various signal lights. In this and in the three subsequent graphs, each data point represents the group mean of each *S*'s six responses to each light. Additional graphs were prepared for each physiological measure separating in each case the first two responses to each light, the second two and final two. Since these figures failed to show any adaptation or other systematic trial-by-trial variation, they are not presented in this report.

Figure 2 shows the mean group decrease in skin resistance to each of the four stimuli mentioned above. The mean GSR to the light which signaled

---

Insert Fig. 2 about here

---

the _Ss_ to breathe normally was 2600 ohms, began after 2 sec., peaked at 4 sec. and still had not returned to its pre-stimulus level after 20 sec. The latency of the GSRs to each of the other three lights was also 2 sec. and the duration in every case was greater than 20 sec. The results of _t_ tests which were used to compare the mean peak amplitude of GSRs to each type of breath are shown in Table 1. As can be seen in this table, only the difference between the GSRs to the slightly deeper breath vs. the deep and fast breath was significant.

Figure 3 depicts the effects of the four respiratory stimuli on the mean heart rate of the 20 _Ss_. Unlike the GSR, heart rate appears to have

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Insert Fig. 3 about here

---

been uneffected by the signal light which indicated "breathe normally." The other interesting aspect of these data is the deceleration phase of the heart rate response to the light which signaled the _Ss_ to breathe deeply and fast. As can be seen in the figure, the magnitude and the peak latency of the response to the deep and fast light and the deep and slow light during the acceleration phase were approximately equal: 98 and 97 beats per min., (Table 1 shows no difference) and a 5 beat latency from light onset. However, the deceleration response to the deep and slow light was 76 beats per min., took 10 beats to peak and had not returned to its pre-stimulus level after 15 beats. On the other hand, the deceleration response to the deep and fast light was only 83 beats per min., took 9 beats to peak and returned to pre-stimulus level in only 12 beats. Table 1 shows that the t value obtained for the heart rate comparison between the negative peak amplitude (deceleration) to the deep and fast vs. deep and slow breaths was significant at the .001 level. As can be seen, in every respect the deceleration response to the deep and fast light was much less than the deep and slow light--and even less than the response to the light which signaled the Ss to breathe only slightly deeper than normal.

Vasomotor effects of the four respiratory stimuli analyzed in terms of pulse volume are shown in Figure 4. Since it was not possible to equate

Insert Fig. 4 about here

responses across Ss, each S's pulse volume was determined as a percent of the mean height of his five pre-stimulus pulses. Here, like the GSR results but unlike the heart rate data, there was a distinct response to the light which indicated that the Ss should breathe normally. This response began 4 heart beats after the onset of the light, peaked at 6 beats, with a peak constriction of 90 percent of the pre-stimulus level, and took 11 beats to return to normal level. The responses to the other three lights, both latency and magnitude, appear to be what would be expected in terms of the latencies and magnitudes of the respective inspirations. Table 1 shows that the pulse volume response to the slightly deeper vs. deep and fast breath, and slightly deeper vs. deep and slow breath were significantly different.

Discussion

Empirically derived figures have been presented showing the relationship of four types of deep breaths to the latency, magnitude and duration of vasomotor, heart rate and galvanic skin responses. The major interest in this study was in determining the effects of isolated deep inspirations on ANS responses. In this respect, the stimuli used here differed from the earlier study of Westcott and Huttenlocher (1961) in which the effects of repeated respiratory maneuvers on heart rate were studied. The more recent study of Engel and Chism (1967) studied the effects of unusual breathing rates but not depth on heart rate and finger pulse volume.

The basic results of this study support the findings of earlier investigators (e.g., Sharpey-Schafer, 1965; Brener, 1967; Kuno, 1956): deep breaths are accompanied by vasoconstriction in the fingers, an increase followed by a decrease in heart rate, and a GSR. In general, the extent of the ANS disturbance varied directly with the depth of the inspiration. Two exceptions to these basic findings are considered to be worth mentioning.

The first of these findings was the absence of a heart rate response to the light which signaled the Ss to continue breathing normally. Perhaps the more surprising result was the continued presence of a substantial pulse volume and GSR to this control light through all six trials. The important finding, however, was thought to be this differential ANS effect. The data for individual trials were examined with the expectation that the GSRs and vasoconstriction responses would show adaptation over the six trials, but this was not the case. There was no change over trials for any of the three ANS responses. The fact that vasoconstriction and GSRs are sympathetic effects whereas heart rate is controlled by the sympathetic and parasympathetic nervous systems seems to indicate that in this quasi-learning situation heart rate was predominantly under parasympathetic control. It should be noted that the latencies of the heart rate responses obtained to actual deep breaths in this study point to a decrease in vagal tone (Dykman and Gantt, 1959) rather than increased sympathetic activity as the primary cause. The role of vagal inhibition in heart rate acceleration immediately following the onset of exercise has been recognized for many years (Gasser and Meek, 1914).

The second interesting finding in this study was the difference in the deceleratory heart rate response to the deep and fast, and deep and slow breaths. As was stated above, the acceleratory phase of the heart rate response to these two rates of inspirations was identical in both magnitude and latency, as were the GSR and pulse volume responses. However, for deceleration, it was found that the deep and slow breath produced a significantly larger and longer-lasting response. This finding seems to emphasize the fact that two separate mechanisms are responsible for the biphasic heart rate response to deep breaths. The acceleratory component appears to be controlled solely by the depth of inspiration. The deceleratory aspect, on the other hand, seems to be predominantly controlled by the slowness of the breath. The possibility is raised, however, that the deceleratory response is brought about through the interaction of the speed and depth of the breath since the deceleratory response for the slightly deeper than normal breath (which was taken at the same approximate speed as the deep and fast breath) was greater in both magnitude and duration than the response to the deep and fast inspiration.

Table 1

Summary of *t* Values Obtained from Comparisons

of Peak Amplitudes

Dependent Measure	Respiratory Maneuver											
	Normal vs. Slightly Deeper			S.D. vs. Deep & Fast			S.D. vs. Deep & Slow			D. & F. vs. D. & S.		
	t	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*
Respiration	6.60	19	.001	7.75	19	.001	8.09	19	.001	1.54	19	*
GSR	1.92	19	*	2.15	19	.05	1.04	19	*	.81	19	*
Heart Rate: Positive	**			4.37	14	.001	4.18	14	.001	.07	14	*
Negative	**			1.31	14	*	3.13	14	.01	4.39	14	.001
Finger Pulse Volume	1.19	15	*	4.51	15	.001	3.52	14	.01	.47	14	*

* *p* .05

** No noticeable effect of a normal breath.

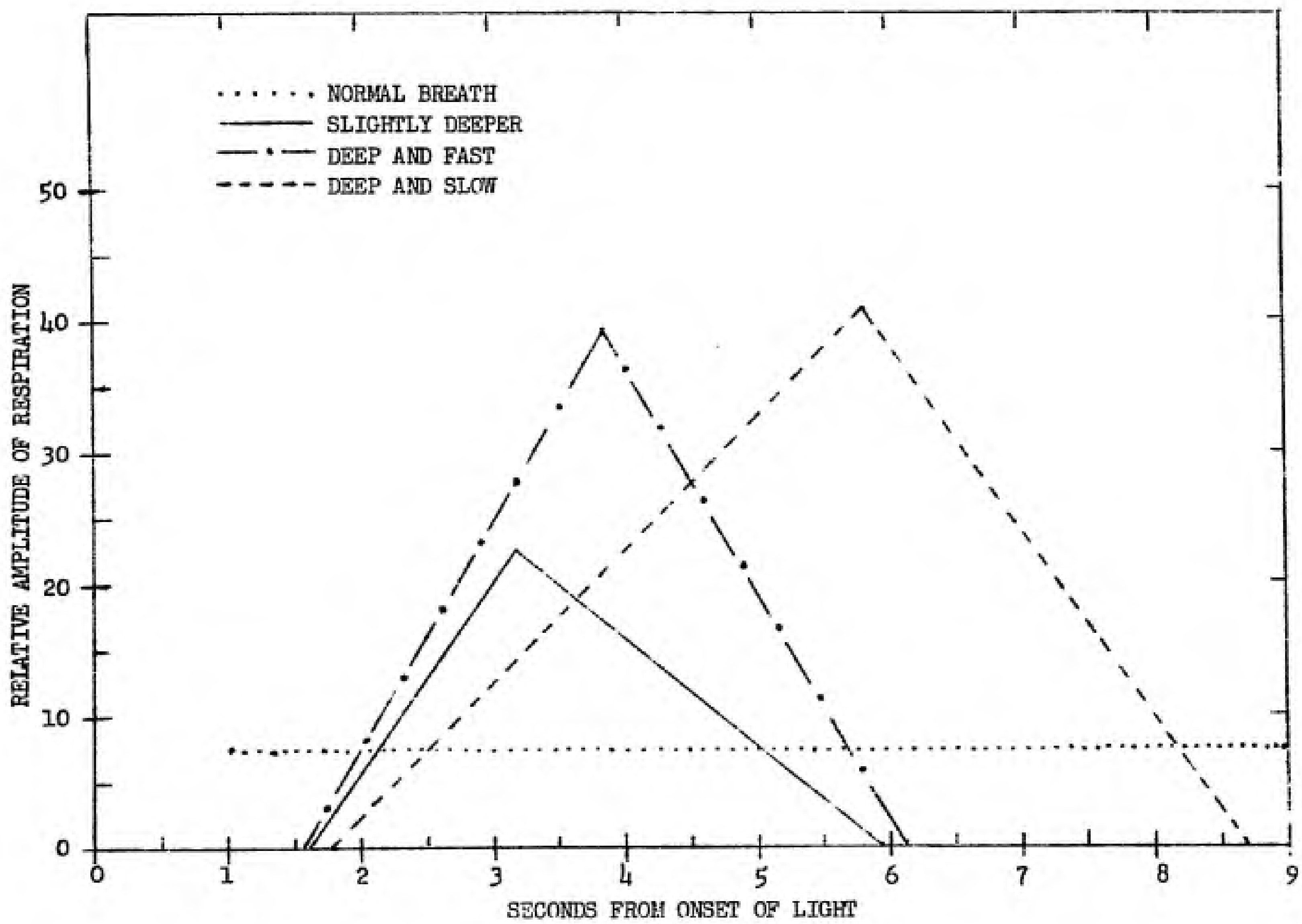
NORMAL BREATH
SLIGHTLY DEEPER
DEEP AND FAST
DEEP AND SLOW
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
RELATIVE AMPLITUDE OF RESPIRATION
SECONDS FROM ONSET OF LIGHT

Fig. 1

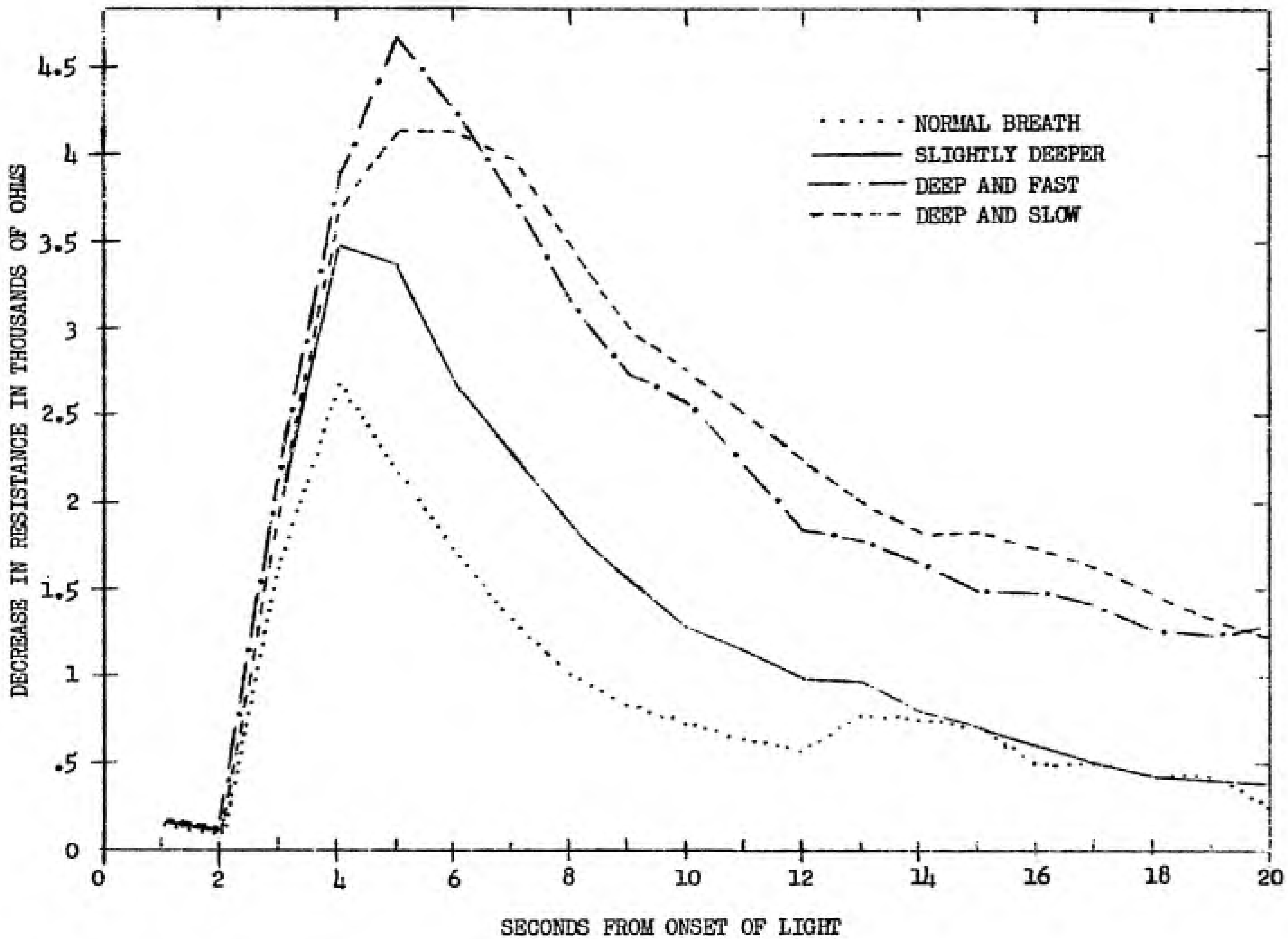
NORMAL BREATH
SLIGHTLY DEEPER
DEEP AND FAST
DEEP AND SLOW
DECREASE IN RESISTANCE IN THOUSANDS OF OHMS
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
0
2
4
6
8
10
12
14
16
18
20
SECONDS FROM ONSET OF LIGHT

Fig. 2

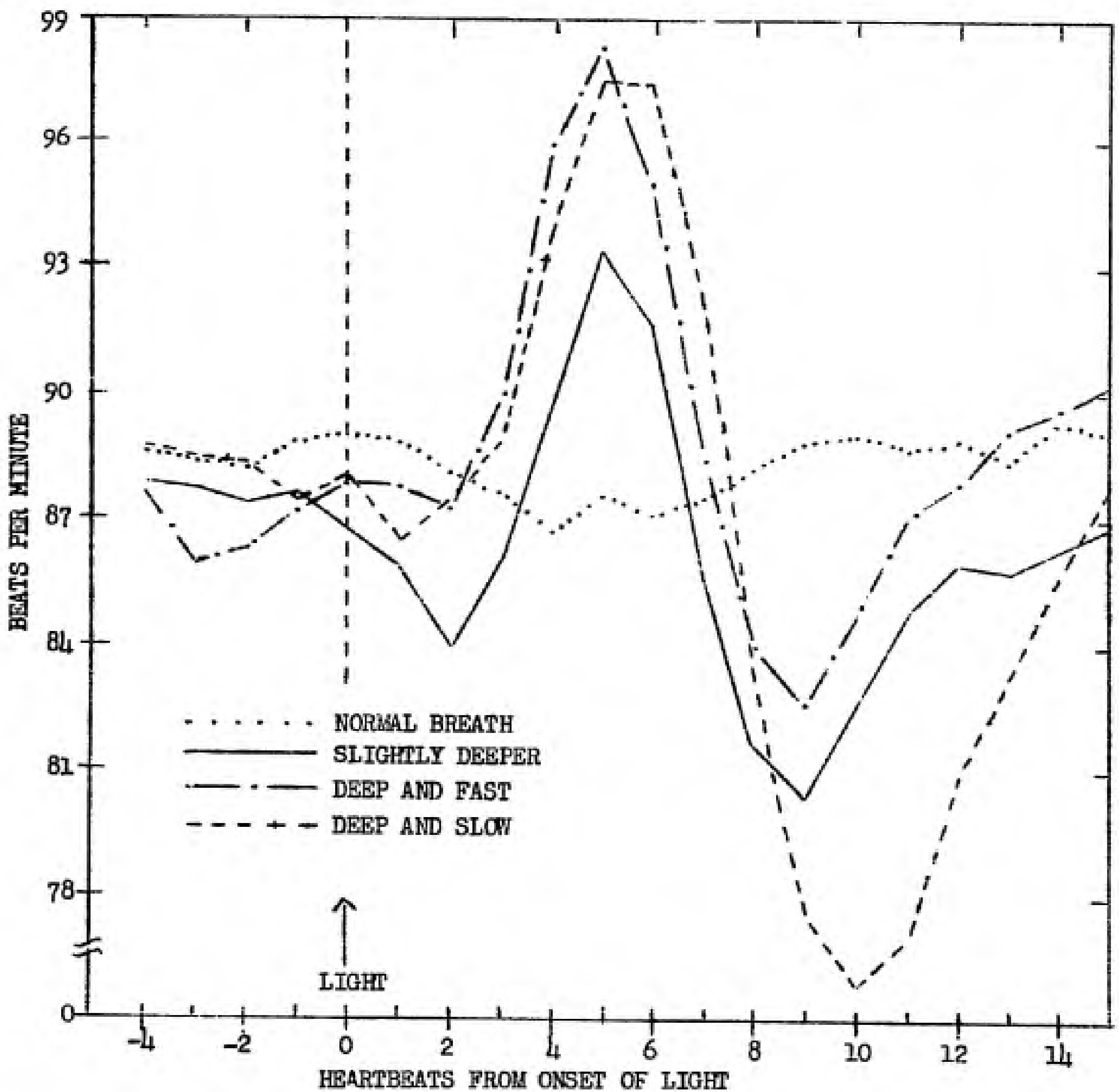
99
96
93
90
87
84
81
78
0
BEATS PER MINUTE
NORMAL BREATH
SLIGHTLY DEEPER
DEEP AND FAST
DEEP AND SLOW
LIGHT
-4
-2
0
2
4
6
8
10
12
14
HEARTBEATS FROM ONSET OF LIGHT

Fig. 3

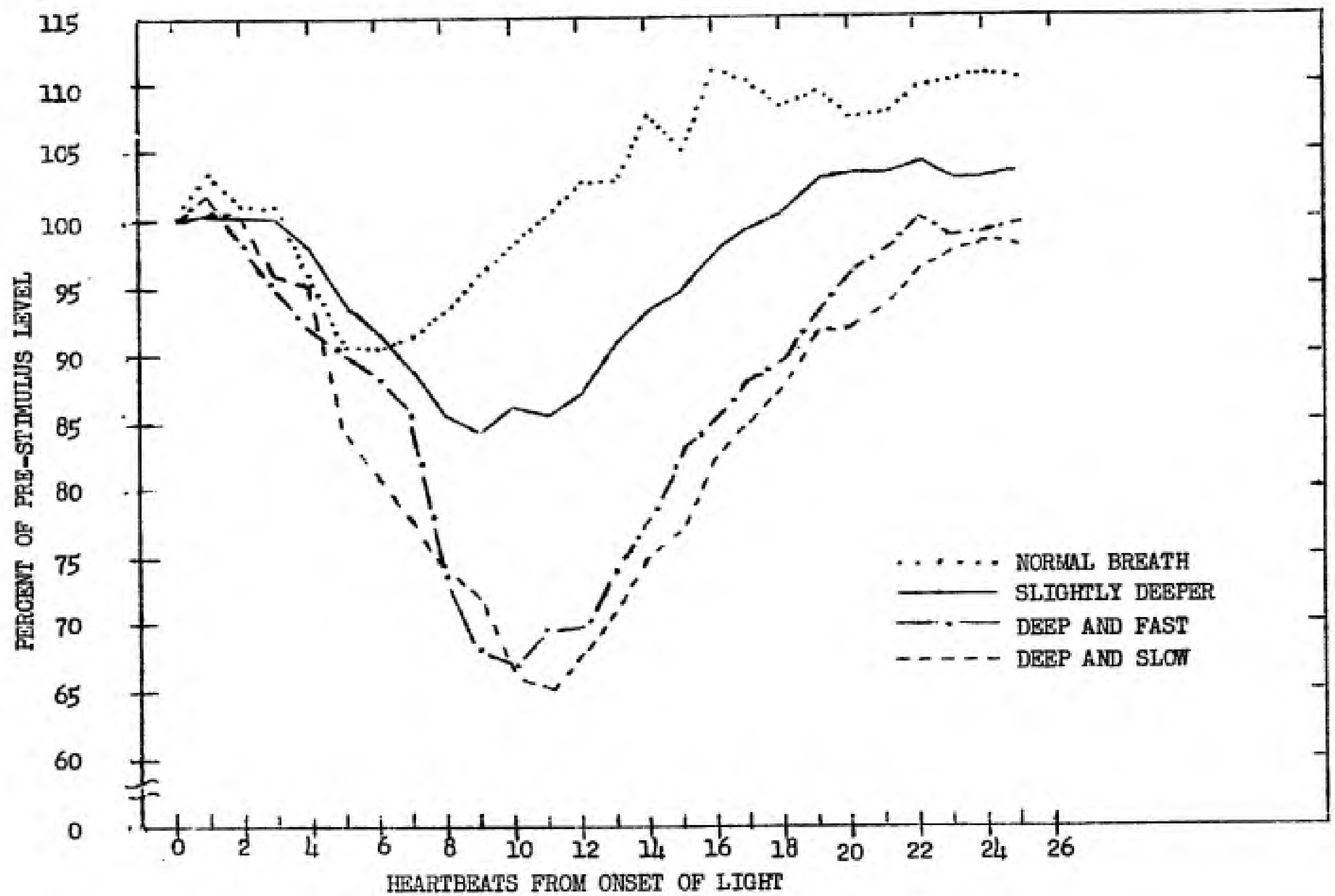
115
110
105
100
95
90
85
80
75
70
65
60
0
PERCENT OF PRE-STIMULUS LEVEL
0
2
4
6
8
10
12
14
16
18
20
22
24
26
HEARTBEATS FROM ONSET OF LIGHT
NORMAL BREATH
SLIGHTLY DEEPER
DEEP AND FAST
DEEP AND SLOW

Fig. 4

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Figure Captions

Figure 1. Mean relative amplitude of four types of breaths taken by the subjects.

Figure 2. Mean group decrease in skin resistance to each of the four respiratory stimuli.

Figure 3. Mean group heart rate to the four respiratory stimuli.

Figure 4. Mean group finger pulse volume in response to each of the four respiratory stimuli.

Footnote

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13. ABSTRACT

The effects of four types of deep breaths on the latency, the magnitude and the duration of finger volume pulse, heart rate and galvanic skin responses were studied in a quasi-learning situation. The respiratory stimuli were normal inspirations, three times deeper than normal, six times deeper and fast, and six times deeper and slow. Twenty Ss took each type of deep breath in random order six times in response to specific lights. Graphs and statistical tests are presented summarizing the above relationships and two unexpected findings are discussed.

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