

BRIEF COMMUNICATION

SYNCHRONIZATION OF RESPIRATION *

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In order to study synchronization of respiration, three different videofragments were presented to 21 normal subjects. Each fragment showed a 'therapeutic interview' specially performed for this purpose, with a 'patient' breathing in a particular way. The respiration of model 1 was deep, slow and clearly audible, the pattern of model 2 was rapid, superficial and slightly audible and that of model 3 was normal and hardly perceptible. The fragments were presented in three different sequences and each sequence was followed by seven subjects. Respiration amplitude (V_T), respiration irregularity (SD of V_T), respiration frequency (RF) and frequency of skin conductance responses (SCRF) were measured. Changes in mean values of these variables were demonstrated during the fragments; an increase in RF was the most pronounced and reliable change. These 'overall' physiological changes did not support the synchronization hypothesis, nor were they at variance with it: they seemed to be effects of attention. A detailed (cycle by cycle) analysis did reveal a synchronization effect in fragment 1. The number of cycles in the subject which were in rhythm with the model's respiration was significantly larger than could have been expected by chance. The effect of synchronization, however, was small and transient as it did not affect the mean RF and V_T of fragment 1.

1. Introduction

This study resulted from an interest in the role of learning in the development of deviant respiratory behaviours (like hyperventilation). Synchronization was studied as a step towards direct investigation of one form of learning, namely imitation learning. A relation between both phenomena seems obvious: synchronization might be the start of imitation learning.

The direct aim of this experiment was to see whether synchronization could be demonstrated in a situation which was supposed to be most favourable for its occurrence. Relevant factors would seem to be the presence of a clearly detectable respiration pattern and the subject's emotional involvement with the model. To enhance involvement the models played the role of 'patients' who were speaking about their personal problems. Video presentation of the models was chosen to standardize the experimental situation.

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2. Method

2.1. Subjects

The subjects were 21 paid volunteers, 16 men and 5 women, ranging in age from 19 to 28 years.

2.2. Procedure

Each subject saw three video-fragments. Fragment 1 showed a 'patient' whose breathing was deep, slow and clearly audible and visible. The pattern of 'patient' 2 was rapid and superficial, thereby mostly visible and slightly audible. The 'patient' of fragment 3 was breathing normally and not visibly or audibly. The respiratory frequency of the three models was resp. 9.7, 24.7 and 11.4 cy/min. The fragments were presented in three different sequences (1, 2, 3; 2, 3, 1; 3, 1, 2). Each sequence was given to seven subjects.

At the start of the experiment the subject was instructed and physiological transducers were attached. The subject was given 'fake' instructions with regard to the aim of the experiment. After a rest period of 10 min the three fragments were shown, each of 5 min duration and separated from each other by 5 min intervals.

2.3. Apparatus

Respiration was measured with two mercury-filled strain gauges, attached in the thoracic and abdominal regions. After the conversion from resistance to potential changes both respiratory signals were added electronically and a single reading represented the total chest and abdominal circumferential change was recorded.

Before addition the ratio between circumferential change and potential change was made equal for both channels by means of the so called 'isovolumetric manoeuvre' (Shapiro and Cohen, 1965). Skin conductance (SC) was measured with silver—silverchloride electrodes, attached to the volar surfaces of the middle phalanges of the second and fourth finger of the non-writing hand. A constant-voltage coupler was used, built according to Lykken and Venables (1971).

2.4. Data treatment

All positive conductance changes $\geq 0.02 \mu\text{Mho}$ were counted as SC responses. The respiration amplitude (or tidal volume: V_t) of every cycle was measured in the inspiration phase. As a measure of irregularity of respiration the SD of V_t values was used. Frequency of SCRs (SCRF), mean V_t , SD of V_t and respiratory frequency (RF) were computed for the three experimental periods (ExP) and the control periods (CP = the last 2 min of the rest period and of the intervals between the fragments).

The Wilcoxon matched-pairs signed-ranks test was always used, except for V_t and SD of V_t . For amplitude values the sign test was used because the strain-gauge method gives only relative values with a different ratio to the absolute V_t in litres for each subject. All the tests were two-tailed and significance level was always at 0.05.

Changes in mean values of respiratory variables may be caused by synchronization, but may also occur as a consequence of other processes such as emotional reactions or attentional effort. Decisive conclusions about the presence of synchronization can only be drawn from an analysis of the direct time relation between the respiratory patterns of subject and model. In designing an analysis strategy one has to deal with the difficulty that there are many possible forms of synchronization, from complete similarity in form to minor effects such as hesitations in the respiration of the subject when the model starts a new inspiration. Inspection of the curves gave two indications of synchronization: (a) sometimes the subject seemed to bring his inspiration in phase with that of the model; and (b) sometimes the subject seemed to slow down his respiration so as to be in rhythm with the model's respiration. Both aspects can be seen in fig. 1.

A cycle of the subject which started during the inspiration phase of a model's cycle was marked as an 'A cycle'. A cycle of the subject which started as the only one during one cycle of the model was marked as a 'B cycle'. The number of A and B cycles which occurred by chance were called 'A' and 'B' cycles' and were estimated as follows: The number of A' cycles is given by the ratio between the inspiration time (IT) and the total respiration time (RT) of the model, multiplied by the number of cycles (N) produced by the subject: the number of A' cycles = $(IT/RT)_{\text{model}} \times N_{\text{subject}}$. The number of B' cycles was estimated by replacing the respiration pattern of the subject by a series of cycles with equal duration and with the

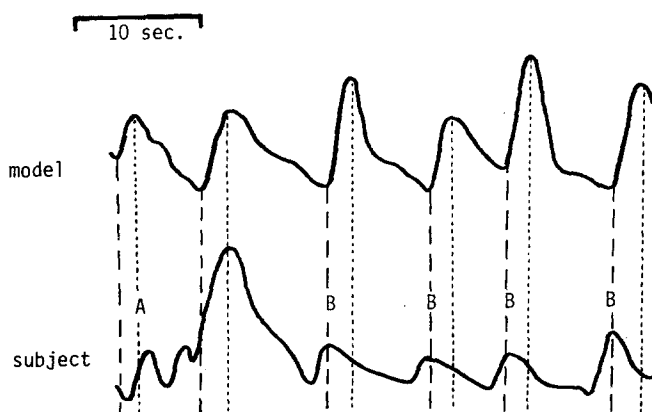


Fig. 1. An illustration of synchronization of respiration.

same mean frequency as the old pattern. With this artificial respiration pattern the number of B' cycles was determined in the same way as was done before with the B cycles. To have a more reliable estimate this analysis was performed three times – starting at different fixed points with respect to the model's respiration – and the mean of these three values was used.

Synchronization analysis was restricted to fragment 1, because the method of estimating the number of B' cycles is only suitable if the RF of the subject is higher than the RF of the model. This restriction will not influence final conclusions because the 'sighing' respiration of the model of this fragment is expected to promote synchronization more than the other respiration patterns.

3. Results and discussion

There was a significant difference between the number of B and B' cycles ($0.01 < p < 0.02$), but not between the number of A and A' cycles.

To test whether a high degree of synchronization was related to other physiological characteristics, comparisons were made between a subgroup of six subjects with the highest (B–B') difference and the rest of the group. This subgroup did not differ significantly in any of the following measures referring to fragment 1: (1) the other synchronization index (A–A' difference); (2) the respiratory variables (RF, V_t and SD of V_t); (3) SCRF. There was also no significant difference in RF and SCRF during the first control period, that is, before any fragment was shown. So, subjects who synchronized their respiration most according to the (B–B') index, did not show any peculiarity in respiration. Neither were they more activated according to the skin conductance measure. Likewise they felt no more involved with the problems of the models than the rest of the subjects, as appeared from answers to a post experimental questionnaire. In conclusion it can be said that synchronization seems to be an isolated phenomenon.

Contrary to the results with the (B–B') index the 'overall' physiological measures did not indicate a clear synchronization effect. If the subject had followed the respiration pattern of the model continuously and in an accurate way, the following response patterns should have been found: for fragment 1 an increase of V_t and a decrease of RF; for fragment 2 a decrease of V_t and an increase of RF and intermediate reactions for fragment 3. As can be seen in table 1 only some tests supported the expectations. So, the synchronization – demonstrated for fragment 1 – appeared to be small in effect and transient, because it did not affect the mean RF and V_t .

These results do not disprove occurrence of synchronization, because this does not necessarily imply a continuous and accurate replication of the model's respiration. Neither do they clearly demonstrate its existence. They probably reflect attentional effort of observing the model. Wiersma (1913), Ettema (1967) and Porges and Raskin (1969) found an increase in RF and no change or a decrease in V_t and respi-

Table 1

The physiological response patterns to the video-fragments: (I) significant differences between the experimtnal period (ExP) and the control period (CP); (II) significant differences between fragments in magnitude of responses (ExP-CP).

Fragment	I			II		
	1	2	3	1 vs 2	1 vs 3	2 vs 3
V_t	—	ExP < CP	ExP < CP	—	—	—
SD V_t	—	ExP < CP	—	—	—	—
RF	ExP > CP	ExP > CP	ExP > CP	—	—	2 > 3
SCRF	ExP > CP	—	ExP > CP	1 > 2	—	2 < 3

— $p > 0.05$ (two-tailed).

ratory irregularity in situations that require attention or mental effort.

The small synchronization effect that was found, might be a consequence of the analysis method. For technical reasons we applied the manual technique described instead of the more advanced signal analysis techniques focussed on similarity of the total wave form, such as the cross spectral and the cross correlational analysis. These techniques are powerful in detecting small, common components in two signals. However, constancy in phase difference of the components is required. This demand is not laid down in our method, nor is any similarity in total wave form required. The specific synchronization signs, our test was focussed on, would get lost if the total wave form was used in analysis.

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