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Mental relaxation improves long-term incidental visual memory

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Abstract

Experimental evidence has linked increased arousal to enhanced memory retention. There is also evidence that procedures reducing arousal, i.e., mental relaxation, might improve memory, but conflicting results have been reported. To clarify this issue, we studied the effects of a single session of relaxation training on incidental visual long-term memory. Thirty-two relaxation-naive subjects viewed 280 slides without being told that there would be subsequent memory testing. Afterwards, subjects listened to a 12 min relaxation tape; 16 subjects relaxed by following the instructions (relaxation group), and the other 16 subjects pressed a button whenever a body part was mentioned (control group). While listening to the relaxation tape, high frequency heart rate variability (HRV) was greater and low frequency HRV was lower in the relaxation group, implying effective relaxation and increasing parasympathetic activation. The relaxation group had superior memory retention 4 weeks later ($p = .004$), indicating enhancement of long-term memory performance. This effect could not be explained by retroactive interference experienced in the control group because short-term memory performance immediately after the tape was slightly better in the control group. Retention of materials acquired after the relaxation session remained unaffected, suggesting relaxation has retrograde effects on memory consolidation. Our data demonstrate a favorable influence of relaxation on at least this aspect of learning. Our data also extend previous knowledge on the beneficial effects of ascending parasympathetic stimulation on memory retention in that enhanced long-term memory consolidation may also occur in the presence of central and descending parasympathetic activation triggered by willful psychomotor activity.

Keywords: Memory retention; Heart rate variability; Parasympathetic nervous system; Relaxation training

1. Introduction

Increased arousal, stress hormones, and sympathetic nervous system (SNS) activation have been shown to favor memory retention (Cahill & McGaugh, 1998). Relaxation (involving directed psychomotor techniques) is known to reduce arousal and shift autonomic nervous system function toward increased parasympathetic nervous system (PNS) and reduced SNS activity (Sakakibara, Takeuchi, & Hayano, 1994). This raises the possibility that relaxation might degrade memory processes. However, the existing literature on relaxation induced memory effects is equivocal. Short-term memory has been shown to improve after relaxation in some (Krampen, 1997; Legostaev, 1996), but not all (Rankin, Gilner, & Gfeller, 1993) studies. It has also been suggested that incidental memory improves but non-incidental long-term memory remains unaffected by relaxation (Lindsay & Morrison, 1996). Thus, the impact of relaxation on human memory, especially on incidental long-term memory, remains unclear.

In the present study, we examined whether a single brief relaxation session would improve short-term and long-term memory retention in healthy adult humans. Relaxation training is known to increase heart rate variability (HRV) (Sakakibara et al., 1994). Thus, we also assessed HRV, as well as self-reported relaxation, as

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measures of the effectiveness of the relaxation procedure.

2. Methods

The research protocol was approved by the ethics committee of the Department of Medicine of Basel University Hospital. Participants signed an institutional review board approved informed consent form.

For the acquisition phase, 32 healthy adults (see Table 1) viewed 280 international affective picture system slides (Lang, Öhman, & Vaitl, 1988) (display time: 1.5 s, interstimulus interval: 4 s). They were not told that there would be memory testing. These slides have been used successfully in testing memory for emotional stimuli (Bradley, Greenwald, & Petry, 1992; Buchanan & Lovallo, 2001).

The subjects then listened to a 12 min relaxation tape, consisting of autogenic training elements and breathing instructions. The tape directed the subjects to focus their attention on different body parts in sequence, and suggested that they feel calm, heavy and warm, with relaxed, rhythmic breathing (but not at a specified frequency). Respiration was mentioned only twice during the tape, and the depth of respiration was addressed only at the very end of the tape, just before they were invited to return to their normal state of consciousness. Half of the subjects followed the relaxation instruction (relaxation group), and the other subjects responded to each of the 75 spoken anatomical words (e.g., 'leg') by pressing a button (control group). Afterwards, subjects rated their degree of relaxation from 1 to 6 (6 being the most relaxed).

Table 1
Relaxation and control group characteristics

	Relax	Control	p
Sex	8F:6M	7F:7M	
Age	26 (1)	26 (1)	.93
HR (baseline)	66 (3)	71 (3)	.23
During relaxation			
Subjective relaxation (1–6 scale)	5.3 (0.2)	2.4 (0.4)	<.0001
RF (Hz)	0.26 (0.08)	0.31 (0.05)	.002
HR (bpm)	64 (3)	76 (2)	.003
RMSSD IBI (ms)	54 (7)	35 (5)	.03
Spectral HRV (ln bpm^2)			
0.02–0.06 Hz, very low	1.15 (0.23)	1.25 (0.26)	.77
0.07–0.14 Hz, low	1.02 (0.29)	1.46 (0.26)	.26
0.15–0.40 Hz, high	1.64 (0.18)	1.19 (0.16)	.08
Spectral HRV, normalized (% total power)			
0.07–0.14 Hz, low	28 (3.6)	39 (3.7)	.03
0.15–0.40 Hz, high	43 (3.2)	31 (3.6)	.03

Data are mean (SEM); RF, respiratory frequency (Hz); HR, heart rate (beats per minute); RMSSD IBI, root mean square of successive differences of interbeat intervals (time domain based heart rate variability, HRV, measure); spectral measures of HRV are provided as natural logarithms (ln bpm^2) and % of total power (0.02–0.50 Hz).

Immediately after listening to the tape, subjects performed the first recognition test (RC-1). Of the 280 slides that were presented during RC-1, 140 had been displayed during the acquisition phase. Subjects indicated by yes/no button press as quickly as possible whether or not they had previously seen the slide (slides were presented every 4 s, missing and premature (<400 ms) responses were discarded, and no accuracy feedback was given).

Four weeks later (and thus related to longer-term memory), a retention test was performed (RC-2) consisting of the 140 slides shown during acquisition but not during RC-1, plus 140 slides not previously shown. In addition, 70 of the 140 slides shown during RC-1 but not during the initial acquisition phase were presented (RC-3; to examine consolidation of materials acquired after the relaxation treatment). According to signal detection theory, a simple recognition index was calculated: probability of true positive minus probability of false negative (Wickens, 2002). This index varies between +1 (perfect performance), 0 (no recognition at all), and −1 (indicating perfectly opposite performance).

During the 12 min relaxation tape, subjects were in a semi-recumbent position, and a standard electrocardiogram (ECG) was recorded from 6 to 11 min, with analog to digital conversion at 1000 Hz. Interbeat intervals (IBI) and heart rate were determined offline. Hardware and software algorithms used are highly sensitive to R-waves (coefficient of variation less than 0.2%, internal laboratory protocol). Further analysis of the vector characteristics of the R-wave allowed for the determination of a low pass filtered respiratory signal. Mean respiratory frequency calculated from this signal was found to match the dominant respiratory frequency values derived from spectral analysis of IBI data. Each IBI series was plotted on screen and manually examined for artifacts, and adjusted when appropriate. Only artifact free periods of pure cardiac sine rhythms were analyzed. The duration of the final time series was 3–5 min per individual.

High frequency HRV indices reflecting the magnitude of respiratory sinus arrhythmia increase with pharmacological stimulation of the parasympathetic nervous system, and decrease with inhibition of the parasympathetic nervous system (Al-Ani, Forkins, & Townend, 1996; Alcalay, Izraeli, & Wallach-Kapon, 1992), and are considered valid non-invasive measures of cardiac vagal control (Task Force of the European Society of Cardiology & the North American Society of Pacing & Electrophysiology, 1996). Such indices have been successfully applied to stress research demonstrating withdrawal of cardiac vagal control (Buchholz, Schachinger,