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Short communication

Facial nerve activity disrupts psychomotor rhythms in the forehead microvasculature

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ABSTRACT

Forehead blood flow was monitored in seven participants with a unilateral facial nerve lesion during relaxation, respiratory biofeedback and a sad documentary. Vascular waves at 0.1 Hz strengthened during respiratory biofeedback, in tune with breathing cycles that also averaged 0.1 Hz. In addition, a psychomotor rhythm at 0.15 Hz was more prominent in vascular waveforms on the denervated than intact side of the forehead, both before and during relaxation and the sad documentary. These findings suggest that parasympathetic activity in the facial nerve interferes with the psychomotor rhythm in the forehead microvasculature.

1. Introduction

Irritation of the eyes, nose and mouth evokes trigeminal-parasympathetic vasodilatation in the forehead microvasculature (Lambert et al., 1984; Drummond, 1992, 1995a, 1995b), and parasympathetic activity in the facial nerve may also regulate a rhythmic wave of dilatation and constriction of forehead vessels at 0.15 Hz (Perlitz et al., 2004a, 2004b). To investigate this, we monitored forehead blood flow in patients with a facial nerve lesion that compromised parasympathetic outflow to one side of the forehead. Patients also watched a sad documentary, to determine whether sad emotions or crying were associated with parasympathetic vasodilatation or the 0.15 Hz wave in the forehead vasculature.

2. Methods

2.1. Participants

The sample consisted of six women and one man aged between 53 and 77 years with loss of muscle tone on one side of the face following removal of an acoustic neuroma 2–33 years previously. In each case Schirmer's strips no longer induced tears in the ipsilateral eye, consistent with a lesion to the parasympathetic component of the facial nerve. Each participant provided written informed consent for the procedures, which were approved by the Institutional Ethics Committee.

2.2. Procedures

Wide area laser Doppler blood flow probes were attached to each side of the forehead 1–2 cm above the eyebrows and 2–3 cm from the midline. Blood flow data were processed by an MBF3D laser Doppler blood flow monitor (Moor Instruments, Axminster, UK). Respiratory movements and an electrocardiogram were also recorded. Signals were sampled at 200 Hz by a Biopac MP100 data acquisition system, and displayed and processed with Acknowledge software (Biopac Systems, Goleta, California).

Participants reclined in an armchair with their eyes closed for 15 min in a quiet room maintained at 24 ± 1 °C. Four participants then listened to an imagery script and three participants received respiratory biofeedback. Guided imagery was presented in a 15-min audio recording that directed participants to imagine descending a 20-step staircase. They were given suggestions for progressive deepening of relaxation and comfort with each step, and were encouraged to notice feelings of warmth and heaviness in their limbs and trunk (Wright and Drummond, 2000). During respiratory biofeedback, participants synchronized their breathing to a musical template patterned on respiratory movements for 15 min (RESPeRATE, Intercure Ltd., Israel). To decrease respiration rate, the template for exhalation increased slightly across consecutive four-breath periods. Next, they watched a 28-min documentary of a young cancer sufferer's experience of terminal cancer ("It's a Beautiful Day", Australian Story, Australian Broadcasting

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Commission, 2007). Participants afterwards described the documentary as moving and inspirational, and all felt at least slightly sad (mean rating 6.7 on a 0–10 scale). They completed the other relaxation technique 6–35 days later.

2.3. Data reduction

Physiological activity was measured in blocks of 327.3 s (65,536 data points) at the start of each session and during the final periods of relaxation and documentary viewing. Blood flow was expressed as the percent change from levels recorded at the start of the session. As well, interbeat intervals were averaged and breaths were counted manually from the electronic chart record.

Power spectra in each laser Doppler signal were identified with fast Fourier transformation using the computational instructions in Biopac Application Note AS-129 (http://www.biopac.com/ApplicationNotes.asp). Welch's method (Welch, 1967) was used to calculate power spectra for wavebands between 0.02–0.05 Hz (neurogenic range), 0.05–0.12 Hz (myogenic range), 0.12–0.18 Hz (psychomotor range), and 0.18–0.4 Hz (respiratory range) (Perlitz et al., 2004a; Jan et al., 2005). Preliminary analyses indicated that raw power spectra were equivalent on each side of the forehead in each of these bands at each stage of the experiment, as was total power between 0 and 0.4 Hz. However, power spectra differed markedly among patients due, in part, to differences in the strength of the blood flow signal. As arbitrary factors such as the relative density and depth of cutaneous blood vessels influence the strength of laser Doppler signals, the relative strength of each waveband at each measurement point was calculated by expressing power spectra as a proportion of total power.

Differences in blood flow between the denervated and intact sides of the forehead, and changes in respiration rate and the interbeat interval, were investigated with paired t-tests (SPSS Version 17, SPSS Inc., Chicago, Illinois). Normalized power within each frequency band was investigated in Side (denervated versus intact) by Time (before versus during the experimental condition) analyses of variance. Each experimental condition was investigated separately due to the small number of participants. Values are presented as the mean ± standard error, and the criterion of statistical significance was $p<0.05$.

3. Results

3.1. Guided imagery

The interbeat interval increased from 1.02 ± 0.05 s to 1.08 ± 0.04 s during guided imagery ($p<0.05$), consistent with the physiological effects of relaxation. However, respiration rate remained stable (11.5 5 ± 1.1 breaths/min at baseline compared with 12.5 ± 0.6 breaths/min during guided imagery), and blood flow did not change significantly on either side of the forehead (mean decrease 7.9 ± 8.6% on the denervated side compared with 11.2 ± 7.1% on the intact side).

Both before and during guided imagery, power spectra in the psychomotor range were proportionally greater on the denervated than intact side of the forehead (mean during both periods 22 ± 5% of total power on the denervated side compared with 15 ± 3% on the intact side, $p<0.05$). Power spectra were equivalent on each side of the forehead for the other frequency bands, and did not change significantly during guided imagery (Table 1).

3.2. Respiratory biofeedback

Respiration rate decreased from 10.5 ± 0.8 breaths/min to 6.3 ± 1.1 breaths/min during respiratory biofeedback ($p<0.05$), and the interbeat interval increased from 0.99 ± 0.06 s to 1.04 ± 0.05 s ($p<0.05$). However, changes in blood flow were similar on each side of the forehead during respiratory biofeedback (mean decrease 0.1 ± 10.3% on the denervated side compared with 11.4 ± 2.5% on the intact side; difference not significant).

Power spectra in the myogenic range increased from 19 ± 4% to 34 ± 6% of total power during respiratory biofeedback ($p<0.05$) due, in part, to phase-coupling between respiratory and vascular waveforms at approximately 0.1 Hz (Fig. 1A). However, power spectra were similar on the intact and denervated sides of the forehead in each waveband (Table 1).

Table 1
Relative strength of power spectra on each side of the forehead before and during guided imagery, respiratory biofeedback, and documentary viewing (N = 7).

	Mean ± S.E. (% total power)			
	Before the procedure		During the procedure	
	Denervated side	Intact side	Denervated side	Intact side
Guided imagery				
Neurogenic band	6.7 ± 1.1	8.1 ± 1.8	13.5 ± 3.1	9.7 ± 1.9
Myogenic band	13.2 ± 4.0	18.9 ± 5.0	18.7 ± 5.8	21.9 ± 4.9
Psychomotor band	21.0 ± 7.7	14.1 ± 4.2	23.6 ± 5.2	16.0 ± 4.7
Respiratory band	4.5 ± 1.0	5.2 ± 0.9	9.6 ± 1.9	10.3 ± 2.4
Respiratory biofeedback				
Neurogenic band	7.1 ± 0.9	9.9 ± 2.6	8.7 ± 1.6	12.6 ± 2.3
Myogenic band	16.2 ± 4.9	22.5 ± 4.1	32.9 ± 8.5	35.5 ± 5.6
Psychomotor band	23.5 ± 7.4	17.1 ± 4.0	27.0 ± 4.4	19.6 ± 5.4
Respiratory band	6.8 ± 1.3	7.4 ± 1.1	5.1 ± 0.7	7.8 ± 1.4
Sad documentary				
Neurogenic band	6.9 ± 1.3	12.5 ± 2.4	10.7 ± 3.4	13.1 ± 4.0
Myogenic band	19.0 ± 5.7	20.4 ± 4.6	17.8 ± 3.4	15.6 ± 2.3
Psychomotor band	26.6 ± 6.4	16.4 ± 3.5	47.0 ± 10.3	27.1 ± 10.2
Respiratory band	5.3 ± 0.9	7.0 ± 1.4	6.5 ± 1.2	4.8 ± 0.9

3.3. Documentary

Respiration rate increased from 11.3 ± 1.0 breaths/min to 13.1 ± 1.0 breaths/min ($p<0.05$), consistent with the sadness described by participants when they watched the documentary. However, the interbeat interval remained stable (1.01 ± 0.05 s at baseline compared with 1.03 ± 0.05 s during the documentary), and increases in forehead blood flow were similar on each side of the forehead (5.5 ± 10.6% on the denervated side compared with 9.4 ± 13.2% on the intact side).

Both before and during the documentary, power spectra in the psychomotor range were proportionally greater on the denervated than intact side of the forehead (mean during both periods 36 ± 8% of total power on the denervated side compared with 22 ± 4% on the intact side, $p<0.05$). In addition, power spectra in the psychomotor range increased on the denervated side of the forehead during the documentary (from 26.6 ± 6.4% of total power beforehand to 47.0 ± 10.3% of total power during the documentary; $p<0.05$), but did not changes significantly on the intact side of the forehead (Table 1). No other changes or differences between sides were statistically significant. However, respiratory and vascular waveforms were associated in some instances (Fig. 1B–C). Power spectra in the other wavebands were similar on both sides of the forehead.

4. Discussion

Vascular rhythms reflect the integrity of several important physiological activities (Bernardi et al., 1996). For example, oscillations, particularly between 0.18 Hz and 0.40 Hz, may be produced by mechanical forces generated during respiration that propagate waves of blood flow throughout the vascular system at base and harmonic frequencies of the breathing cycle; in addition, respiratory changes may alter cardiac contractility and hence blood flow (Bernardi et al., 1997). Rhythms at 0.1 Hz are linked with baroreflex control of arterial blood pressure and with coordinated vascular smooth muscle contractions (Sleight et al.,