Experimental modulation of mood by acoustic stimulation and its effect on exertional dyspnoea

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ABSTRACT

We examined the interactions between acoustically driven mood modulation and dyspnoea. Following familiarisation, 18 healthy participants attended three experimental sessions on separate days performing two 5 min treadmill tests with a 30 min interval per session while listening to either a positive, negative or neutral set of standardised International Affective Digitised Sounds (IADS). Participants rated intensity and affective domains of dyspnoea during the first exercise test and mood during the second. Mood valence was significantly higher when listening to positive (mean (95% CI): 6.5 (5.9–7.2)) compared with negative sounds (3.6 (2.9–4.4); p<0.001). Dyspnoea *intensity* and *affect* were statistically significantly lower when listening to positive (2.4 (1.8–2.9) and 1.3 (0.7–1.9)) compared with negative IADS (3.2 (2.3–3.7), p=0.013 and 2.3 (1.3–3.3), p=0.009). These findings indicate that acoustically induced mood changes influence exertional dyspnoea.

INTRODUCTION

Dyspnoea is a debilitating symptom in individuals suffering from chronic cardiorespiratory and other conditions.[1 2] Prevalence of dyspnoea is high and set to increase while therapeutic options for symptom palliation are limited.[1] Recent reports indicate that experimental viewing of standardised mood-modulating stimuli with pleasant/unpleasant images (International Affective Picture System—IAPS[3]) decreases/increases dyspnoea perception in both healthy participants and those with COPD.[4 5]

The current study investigated the effect of mood-modulating acoustic sounds (international affective digitised sounds—IADS[6] system) on exertional dyspnoea in healthy subjects. Unlike IAPS, IADS offers a feasible approach for integration into both activities of daily living and rehabilitation programmes, but its effect on dyspnoea has not been explored.

METHODS

We recruited 18 healthy individuals following approval by Griffith University Human Research Ethics Committee. Participants visited the laboratory on four occasions approximately 1 week apart.

Following a familiarisation session, participants performed two identical 5 min treadmill exercise tests, separated by 30 min, on each of 3 days while listening to mood-modulating IADS[6] sound clips. We selected 3 sets of 31 sound clips with high (pleasant), medium and low (unpleasant) valence (online supplementary table). Each sound clip was played for 6 s through headphones and separated by a 2 s interval. At minute intervals, sound clips were paused to allow subjective ratings of either mood or dyspnoea. Mood was rated using the standard 9-point pictorial scale (self-assessment manikin—SAM).[5] Two versions of SAM were displayed consecutively for 7 s each (53–67 s of each minute), with mood ratings of valence (extremely unhappy to extremely happy; 1–9) and arousal (extremely calm to extremely excited; 1–9) according to a standard script.[5] Dyspnoea was similarly rated using a 0–10 numeric scale for the sensory (intensity) and affective (bother/unpleasantness) domains using a script modified from previous studies.[5] For the sensory domain, '0' represented no shortness of breath (SOB) and '10', a level that would force cessation or easing of exercise. For the affective domain, '0' indicated that SOB was not at all bothersome/unpleasant, and '10' that it was extremely bothersome. Dyspnoea was rated throughout the first exercise bout followed by a single 0–10 rating of perceived leg fatigue at the end of exercise.

Participants exercised at 25% gradient at an individualised speed (~4 kph) targeted to achieve 85% age-predicted maximum heart rate. ECG and pulse oximetry were monitored, and a face mask enabled measurement of ventilation/gas-exchange (Quark, Cosmed srl-Italy). At each session, participants attended to a single set of sound clips (ie, positive, negative or neutral) randomly ordered between subjects. Baseline mood was assessed prior to exercise (Brunel Mood Scale). Ventilation ($\dot{V}_E$), oxygen uptake ($\dot{V}O_2$) carbon dioxide output ($\dot{V}CO_2$), tidal volume (V_T), respiratory frequency (f_R) and heart rate (HR) were averaged over 1 min periods.

Cardiorespiratory measures, together with ratings of mood or dyspnoea, were analysed using two-way repeated measures analysis of variance (ANOVA). Baseline mood and end-exercise leg fatigue were analysed using one-way ANOVA. Any condition-related significant differences were explored using Fisher's least signifcant difference (LSD) post-hoc pairwise comparisons. Two-way repeated measures analysis of covariance (ANCOVA) was used to examine the potential confounding effects of any physiological variable. The association between the individual domains of dyspnoea was analysed using Pearson's correlation coefficient. Statistical significance was accepted at $p<0.05$.

RESULTS

Subjects

Table 1 shows participants' characteristics. No exertional arterial desaturation or cardiac arrhythmias were observed.

Table 1 Characteristics of participants

Characteristic	Value
Men/women	10/8
Age, years	29.6±7.4
Body mass index , kg/m^2	24.6±3.3
Systolic blood pressure, mm Hg	114.0±11.8
Diastolic blood pressure, mm Hg	72.7±8.7
Forced vital capacity , % predicted	100.6±15.3
FEV_1, % predicted	94.7±15.6

Values presented as means±SD.
FEV_1 forced expiratory volume in 1 s.

Baseline mood

There was no statistically significant difference in baseline mood scores between the three experimental conditions (table 2A).

Cardiopulmonary measures

There was a condition-related significant difference for $\dot{V}_E$ (p=0.045), $\dot{V}CO_2$ (p=0.028) and f_R (p=0.042), (table 2B showing peak values) whereas $\dot{V}O_2$, HR and V_T remained statistically similar between different mood states. Post-hoc comparisons revealed that for the negative condition, $\dot{V}_E$ was statistically significantly greater than in the positive condition (p=0.045). $\dot{V}CO_2$ for the negative condition was significantly greater than in the positive condition (p=0.041) and f_R was greater for the negative condition compared with the neutral condition (p=0.035).

Table 2 Baseline mood state and selected end exercise cardiopulmonary and symptom responses for different experimental conditions

	International affective digitised sounds set		
Variable	Positive	Neutral	Negative
(A) Baseline mood state			
Tension	1.4 (0.4–2.9)	1.6 (0.1–3.1)	1.5 (0.1–2.9)
Depression	0.4 (0.0–0.8)	0.2 (0.0–0.4)	0.5 (0.1–1.0)
Anger	0.4 (0.2–0.6)	0.5 (0.1–0.9)	0.3 (0.0–0.8)
Vigour	8.8 (7.0–10.6)	8.3 (6.6–10.1)	7.3 (5.4–9.3)
Fatigue	2.1 (0.7–3.4)	2.6 (1.4–3.8)	2.8 (1.7–4.0)
Confusion	0.4 (0.2–0.6)	0.4 (0.1–0.8)	0.5 (0.1–0.9)
(B) End exercise cardiopulmonary variables			
Ventilation (L/min)	69.2 (59.5–78.9)	69.9 (59.0–80.8)	72.9 (62.1–83.9)*
Carbon dioxide output (L/min)	2.5 (2.2–2.9)	2.6 (2.2–3.0)	2.7 (2.3–3.0)*
Respiratory frequency (L/min)	34.3 (31.8–36.9)	34.0 (31.6–36.5)	36.0 (33–39)*
(C) End exercise dyspnoea and leg fatigue			
Leg fatigue	2.9 (2.1–3.7)	3.7 (2.7–4.7)	3.3 (2.5–4.1)
Dyspnoea intensity	3.2 (2.7–3.8)	3.7 (2.9–4.5)	4.4 (3.4–5.4)*
Dyspnoea bother	1.6 (1.2–2.0)	2.4 (1.4–3.4)	3.3 (2.3–4.3)*

Values presented as means (95% CI), n=18.
*P<0.05 between positive vs negative conditions.
Baseline mood states calculated from 24-item (0–4 rating) Brunel Mood Scale questionnaire prior to exercise (0=not experiencing mood state, 16=strongly experiencing mood state).
End exercise (final minute) values for cardiopulmonary measures showing condition-related significant differences, leg fatigue, dyspnoea intensity and dyspnoea bother.

Auditory mood modulation

The different sets of IADS sounds had a highly significant condition-related effect on mood valence (figure 1A; p<0.001). Post-hoc analysis revealed that compared with neutral, mood valence was significantly higher when listening to positive sounds (p<0.001) and significantly lower with negative sounds (p<0.001). However different sound sets had no effect on mood arousal (figure 1B).

Exertional dyspnoea

There was a condition-related effect for both dyspnoea intensity (p=0.047) and dyspnoea bother (p=0.007) (figure 1C and D). Post-hoc analysis revealed that negative sounds produced greater dyspnoea intensity than positive ones (p=0.013). Negative sounds also induced greater dyspnoea bother compared with both neutral (p=0.048) and positive (p=0.009) conditions. A separate ANOVA confirmed the absence of any systematic test-order effect.

ANCOVA revealed that both dyspnoea intensity and bother remained significantly higher in the negative compared with the positive condition when $\dot{V}_E$, $\dot{V}CO_2$ and f_R were accounted for as confounding variables (p<0.01).

Individual paired responses for dyspnoea intensity and bother revealed: positive r=0.51; neutral r=0.45; negative r=0.44 (p<0.001 in each case).

Leg fatigue

The IADS sound clips had no significant effect on the single end-exercise ratings of leg fatigue (p=0.127) (table 2C). By comparison, end-exercise dyspnoea intensity and bother were significantly higher with negative compared with positive mood (p=0.045 and p=0.004).

DISCUSSION

We have shown for the first time that auditory modulation of positive mood in healthy subjects is associated with significantly lower ratings of exertional dyspnoea intensity and bother compared with negative mood. On the other hand, auditory modulation of mood had no effect on perceived leg fatigue consistent with the idea that these primary exercise symptoms are processed differently by the brain, with dyspnoea being more susceptible to changes in *affect*. Our findings in conjunction with similar studies using standard images[4 5] suggest that mood *per se* (ie, independent of visual input) impacts on this commonly experienced aversive exercise-related symptom. Importantly, while our findings showed that negative mood during exercise was associated with higher levels of $\dot{V}_E$, f_R and $\dot{V}CO_2$, introducing these as covariates, confirmed that mood itself influences exertional dyspnoea. The current findings are in line with very few previous studies, which used music to reduce exercise-induced dyspnoea. However, it is worth noting that those studies used music as a 'distractor' and did not systematically vary the mood state.[7] Nonetheless, von Leupoldt *et al*. (2007) demonstrated that music as a distractor, in addition to reducing dyspnoea, also induced positive mood.[8]

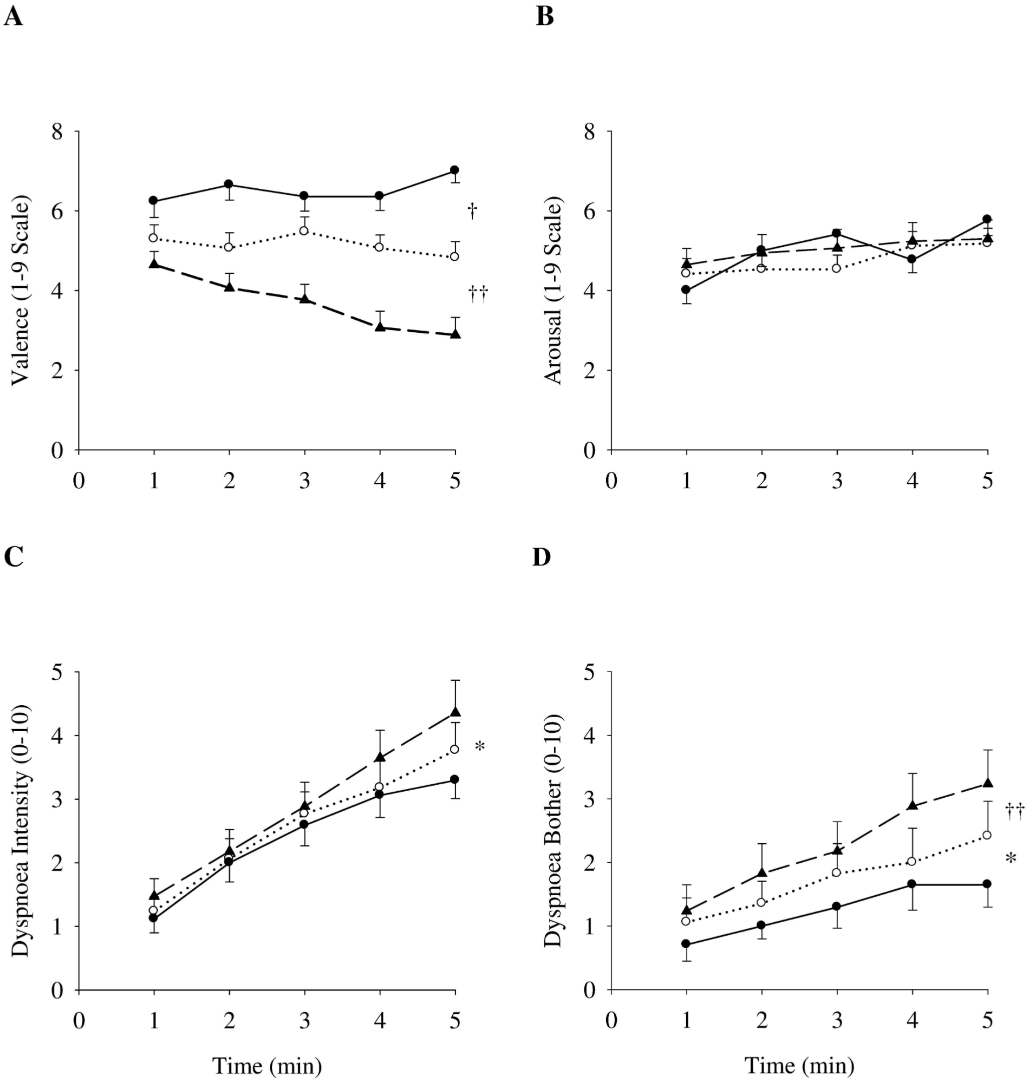

Figure 1 Mean (SEM) ratings of mood valence (panel A), mood arousal (panel B), dyspnoea intensity (panel C) and dyspnoea bother (panel D) during three identical treadmill exercise bouts performed on three separate days in 18 healthy volunteers. During each of the exercise bouts, participants listened to either a positive (●), neutral (**o**) or negative (▲) set of international affective digitised sounds and rated their mood valence (1=extremely unhappy, 9=extremely happy), mood arousal (1=extremely calm, 9=extremely excited), dyspnoea intensity (0=no shortness of breath (SOB), 10=extreme SOB) and bother (0=not at all bothersome, 10=extremely bothersome) at minute intervals. Significant statistical difference ($p<0.05$) between different sound sets represented by * for positive vs negative, † for positive vs neutral and †† for negative vs neutral.

Although the present small study in healthy subjects has limited generalisability to patient populations, it is interesting to address their potential relevance to clinical dyspnoea. There is substantial evidence that the prevalence of anxiety and depression is higher in patients with diseases such as COPD,[9] and there is growing evidence that treating depression and anxiety and improving mood state may be effective in alleviating chronic dyspnoea.[10] These studies indicate that more research is required to explore the effectiveness of psychotherapeutic approaches in the relief of dyspnoea. Auditory modulation of mood could provide one such approach, potentially enabling greater gains in exercise capacity both in terms of rehabilitation outcomes and activities of daily living.

CONCLUSION

The findings from our study indicate for the first time that, as with visual imagery, standardised mood-modulating auditory stimuli are effective in altering the perception of concurrent exertional dyspnoea. This is important since it supports the thesis that mood *per se* is the key factor in mediating this response. This study emphasises that mood enhancement during exercise can be achieved through a simple intervention with the possibility of improved rehabilitation outcomes in clinical populations.

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Contributors PS made the primary contributions to the conception of this work with LH, NRM, SS and LA contributing substantially to its design. PS and LH were primarily responsible for data acquisition, analysis and interpretation and were assisted by LA, NRM and SS. Initial drafting of the manuscript was carried out by LH and PS with LA, SS and NRM providing critical revision.

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