Differentiation Between the Sensory and Affective Dimension of Dyspnea During Resistive Load Breathing in Normal Subjects*

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Study objective: Dyspnea is the uncomfortable sensation of breathing and is an impairing symptom in a variety of diseases. Like pain, it motivates adaptive behavior to regain homeostasis, and both sensations share various characteristics. Whereas the realization of the multidimensionality of pain was a key contribution to pain research, little is known about a similar multidimensionality in the perception of dyspnea. The present study examined whether sensory and affective aspects of induced dyspnea can be differentiated.

Design: A controlled laboratory study.

Setting: Psychophysiologic laboratory of the Psychological Institute III, University of Hamburg, Germany.

Participants: Ten healthy volunteers aged 24 to 52 years (mean, 35 years).

Interventions: Dyspnea was induced by breathing through inspiratory resistive loads of increasing magnitude (0.99 to 2.33 kPa/L/s), alternating with episodes of unloaded breathing. Inspiratory time (T1) and breathing frequency (f) were continuously monitored. The experienced intensity and unpleasantness of dyspnea were rated after each episode on separate visual analog scales (VASs), which were presented in permuted order. Intraindividual linear regression slopes were calculated separately for both dimensions and compared.

Measurements and results: Breathing through inspiratory resistive loads resulted in increases of VAS ratings for intensity and unpleasantness paralleled by increases in T1 and decreases in f (p = 0.012 and p = 0.003, respectively). The mean regression slope for perceived unpleasantness was higher than for perceived intensity (mean ± SD, 2.83 ± 1.28 and 2.11 ± 1.74, respectively; p = 0.032), indicating stronger increases of unpleasantness with increasing magnitude of resistive loads.

Conclusions: The results show that the sensory and affective dimension of experimentally induced dyspnea can be differentiated in healthy volunteers. The obtained multidimensionality of dyspnea converges with previous reports on similarities between dyspnea and pain. Implications for future studies on the perception of dyspnea are provided.

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Key words: asthma; breathlessness; COPD; dyspnea; pain; perception

Abbreviations: f = breathing frequency; T1 = inspiratory time; VAS = visual analog scale

Dyspnea is defined as the subjective experience of breathing discomfort that comprises distinct sensations, which can vary in their quality and intensity. Like pain, this sensory experience results from a variety of interactions among multiple physiologic, psychological, social, and environmental factors.1 It is a symptom in various cardiopulmonary and other diseases2 and causes reductions in functional status and quality of life, and has a considerable socioeconomic burden.1,3–5 Previous work has shown that both dyspnea and pain are similarly unpleasant, alarming physical sensations that might even be mediated by a common cortical network. Therefore, it has been suggested to adopt successful methods and strategies from pain research, which is by far more advanced, for investigations into dyspnea.6,7 A
major contribution to pain research was the realization of the difference between sensory and affective aspects of this sensation, which led to the development of highly useful pain measurement instruments and intervention techniques. Although first indications seem to suggest a similar multidimensionality of the perception of dyspnea, the experimental evidence for a differentiation between the sensory and affective dimension of induced dyspnea is still insufficient but could be a promising paradigm for future research on dyspnea.

This study examined whether sensory and affective aspects of perceived dyspnea can be differentiated in a sample of healthy volunteers. Therefore, dyspnea was induced with inspiratory resistive loads of increasing magnitude. Perceived intensity and unpleasantness were rated on separate visual analog scales (VASs), and respective intraindividual regression slopes were compared.

**METHODS AND MATERIALS**

**Participants**

Ten healthy, white volunteers were studied. Table 1 summarizes the mean baseline characteristics of the volunteers. Pregnancy, acute complaints of the respiratory tract, or any chronic medical conditions such as asthma, chronic pain, and sensory deficits were exclusion criteria. After giving written informed consent, volunteers underwent screening spirometry. Participants were free to withdraw at any time during the experiment. The study protocol was approved by the local ethical committee.

**Measurement of Lung Function**

Spirometry was performed according to standards published by the European Respiratory Society (Spiroset 3000; Hörmann Medizintechnik GmbH; Munich, Germany). Spirometry was performed with participants standing and using nose clips.

**Inspiratory Resistive Loads**

Respiratory loads, which increase inspiratory time (T) and decrease breathing frequency (f), are commonly used to induce dyspnea by increasing the work and effort of breathing. In this study, volunteers breathed via a mouthpiece through a breathing circuit that consisted of a two-way valve (Jaeger Toennies GmbH; Hoechberg, Germany) while a nose clip was positioned. At the end of the inspiratory port, seven resistive loads of increasing magnitude (0.99, 1.21, 1.43, 1.75, 2.07, 2.19, and 2.33 kPa/L/s) could be applied and removed quickly. No load was presented during baseline conditions.

**Measurement of Ventilation**

To control effects of dyspnea induction, T and f were measured continuously at the mouthpiece using a fast-response transducer (ZAN; Korn Medizintechnik; Nuernberg, Germany). The output signal was conveyed to a biosignal recording unit (MP30; Biopac Systems; Santa Barbara, CA), which was connected with the biosignal software package (Biopac Student Lab Pro; Biopac Systems) run on a notebook (Apple; Cupertino, CA). All data were stored on the notebook and analyzed off-line.

**Measurement of Perceived Sensations**

Dyspnea was generally defined as a sensation of uncomfortable restricted breathing with the notion that all other sensations (eg, uncomfortable seat or nose clip) should not be rated. After each dyspneic and baseline condition, the experienced degree of dyspneic and baseline condition, the experienced degree of intensity (sensory) and unpleasantness (affective) was rated on separate VAS ranging from 0 to 10 cm (0 = not noticeable/unpleasant, and 10 = maximally imaginable intensity/unpleasant). VAS scores for intensity and unpleasantness were permitted in permuted order. Both dimensions were explained in detail with standardized examples, and the experimenter made sure that the phrases were adequately understood.

**Experimental Protocol**

Before the test, participants were familiarized with the apparatus and measurement procedure. After standardized instructions, volunteers were seated in a recliner while the light was dimmed. Participants breathed through the breathing circuit with the nose occluded. During the tests, seven inspiratory resistive loads of increasing magnitude were presented for 1 min each, alternating with 1-min baseline epochs without presentation of resistive loads. After each epoch, the volunteers rated the perceived degree of intensity and unpleasantness on separate VASs presented in permuted order.

**Statistical Analysis**

Results are reported as mean ± SD. T and f were averaged for baseline and for dyspneic conditions and analyzed as dependent variables in separate one-way repeated-measures analyses of variance. For each volunteer, separate linear regressions were calculated for analyzing the predictive validity of increasing resistive loads on ratings for experienced intensity and unpleasantness, respectively. The intraindividual regression slopes were averaged for each dimension and compared with a pairwise t-test. All analyses were calculated with statistical software (SPSS 11.5; SPSS; Chicago, IL) using a 5% significance level.

**RESULTS**

**Ventilation**

As expected, breathing through inspiratory resistive loads induced a significant increase in T when
compared to baseline conditions (2.16 ± 1.04 s and 1.56 ± 0.68 s, p = 0.012). This was paralleled by significant decreases in $f$ during loaded breathing when compared to baseline conditions (13.05 ± 3.42 breaths/min and 14.64 ± 3.13 breaths/min, respectively; p = 0.003).

Perceived Sensations

VAS ratings for experienced intensity and unpleasantness of dyspnea showed no difference at baseline (0.6 ± 0.5 cm and 1.1 ± 1.1 cm, respectively). Ratings for both dimensions increased with increasing magnitude of dyspnea and showed a plateau at the two highest loads, which might be indicative of a habituation effect. The mean regression slope for unpleasantness (2.83 ± 1.28) was significantly higher than for intensity (2.11 ± 1.74), p = 0.032. As illustrated in Figure 1, this was due to stronger increases in experienced unpleasantness compared with experienced intensity when resistive loads were increasing.

**FIGURE 1.** Mean VAS ratings (±SD) for intensity (Δ) and unpleasantness (▲) of perceived dyspnea during breathing through inspiratory resistive loads of increasing magnitude. Both dimensions show some plateau at the two highest loads, which might indicate a habituation effect. The regression lines represent the group mean of the intrindividual regression slopes for intensity (dotted line) and unpleasantness (straight line). The slope for experienced unpleasantness (affective dimension) is steeper than for experienced intensity (sensory dimension) [p = 0.032], demonstrating a stronger increase of the affective dimension with increasing dyspnea.

**DISCUSSION**

Dyspnea and pain are both unpleasant, alarming physical sensations, resulting from interactions among multiple factors. Because of various similarities, the differentiation between the sensory and affective dimension of dyspnea has been suggested as being a promising avenue for research on dyspnea since a similar differentiation has been a cornerstone of pain research.10,114 Beside the development of widespread multidimensional pain assessment instruments and interventions, neuroimaging studies18 further showed that both dimensions are predominantly mediated by separate cortical pathways. However, a precise differentiation between the sensory and affective aspects of experimentally induced dyspnea has not fully been proven.

In the present study, dyspnea was successfully induced by breathing through inspiratory resistive loads of increasing magnitude, which significantly increased $T_1$ and reduced $f$. These findings correspond with typical effects of studies using resistive loads, which increase the work and effort of breathing.10 Our results show that with increasing dyspnea the perceived unpleasantness increases stronger than the perceived intensity, indicating that the sensory and affective dimension of dyspnea can be differentiated similar to the perception of pain. This observation is in line with first but widely neglected findings. Lehrer and colleagues11 developed a verbal descriptor scale for the assessment of asthma symptoms, with asthmatic patients being able to retrospectively differentiate between the dimensions of intensity, quality, and unpleasantness of their symptoms. The reported scores for unpleasantness were on average higher than scores for the other dimensions. Furthermore, Wilson and Jones10 reported differences between experienced intensity and distress of healthy participants during cycle ergometer exercise, with the descriptor distress containing at least some affective connotation. Similar differences between reported intensity and distress during walking or treadmill exercise were shown in patients with COPD by Carriera-Kohlman and colleagues.12,13 These studies are, however, not comparable with the present study, either due to a rather retrospective nature of assessing asthmatic complaints or due to differences in the perceived dimensions being examined during different tasks.

The reported findings confirm the suggested multidimensionality of dyspnea and underline recent work pointing out the role of psychological aspects in the processing of this sensation. In this regard, particularly negative affectivity has been shown as having an influence on perceptual accuracy.19 Banzett and colleagues14 emphasized the specific importance of the affective dimension of dyspnea in motivating patients to seek help or take medication. This converges with our results in healthy volunteers, showing that increasing dyspnea leads to higher unpleasantness compared to intensity, which in turn under more naturalistic conditions might motivate adaptive behavior to change this unpleasant condi-
It might be interesting in this regard to examine, whether patients with blunted perception of dyspnea have a specific deficit in the affective rather than the sensory aspects of their perceptual processing. Future research is clearly required to assess the different dimensions of dyspnea in dyspneic patient groups, preferentially with varying methods of inducing this sensation, eg, histamine bronchial challenge. In the present study, resistive loads of monotonically increasing magnitude were applied in order to mirror the character of naturally occurring dyspnea, where the sensation of increased work and effort of breathing develops progressively the more the respiratory muscles are weakened by working against an imposed load, eg, during hyperinflation or bronchoconstriction. However, repeated randomized presentations of different loads which have been used in various load detection studies16 might be an alternative method. Furthermore, future studies might investigate the relieving effects of cognitive intervention techniques concerning the affective context or attention state during episodes of dyspnea, which have been successful in reducing the perception of pain.20 Following this lead, it might be useful to examine which dimension of perceived dyspnea (ie, intensity or unpleasantness) is more susceptible to these interventions and in which specific patient group. Since a high association of diseases with dyspneic symptoms (eg, asthma, COPD) and depression has been shown,21,22 a differentiation between the sensory and affective dimension of reported dyspnea in patients with a comorbid depression might be of particular importance and improve the accuracy of the diagnostic process, symptom perception by patients, use of reliever medication, and therapeutic interventions. This is underlined by previous studies19,23,24 demonstrating that high negative affectivity reduces the accuracy of dyspnea perception. Moreover, since sensory and affective components of pain have recently been localized in discreet cortical structures,18 which can be manipulated separately,25 a similar functional differentiation might also exist and be examined for the processing of dyspnea.6,7

CONCLUSION

In summary, our findings show that healthy volunteers are able to differentiate between the sensory and affective dimension of experimentally induced dyspnea. These results add further incidence to the perceptual similarities between dyspnea and pain and provide new strategies for future investigations into dyspnea.

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