Descriptors of Breathlessness in Healthy Individuals*

Distinct and Separable Constructs

Andrew Harver, PhD; Donald A. Mahler, MD, FCCP; Richard M. Schwartzstein, MD, FCCP; and John C. Baird, PhD

Study objectives: We tested the hypothesis that descriptors of breathlessness represent distinct and separable cognitive constructs, and predicted that the use of descriptors of breathlessness by healthy individuals is the same as their use by patients with cardiopulmonary disease.

Design: Cluster analyses obtained in healthy individuals were compared with those obtained previously in patients who complained of breathing discomfort. In addition, we used multidimensional scaling (MDS) techniques to analyze relationships among descriptors in healthy individuals.

Setting: Public university.

Participants: The participants were 100 healthy individuals (48 men and 52 women) ranging in age between 18 and 65 years (mean, 27.9 ± 11.7 years).

Measurements and results: Participants judged the dissimilarity among pairs of 15 descriptors of breathlessness that were used previously to examine the experience of dyspnea in patients who complained of breathing discomfort. Cluster analysis solutions obtained in the healthy individuals were virtually identical to those obtained previously in patients. Three dimensions (attributes) of breathing discomfort were uncovered with MDS: “Depth and frequency of breathing,” “Perceived need, or urge, to breathe,” and “Difficulty breathing and phase of respiration.” The results did not depend on age, sex, levels of education, or the presence of uncomfortable awareness of breathing with activities.

Conclusions: The relations among descriptors of breathlessness obtained in healthy individuals support the contention that the association of different clusters with different disease states reflects distinct and separable cognitive constructs that are not simply dependent on the presence of an underlying pathophysiology or on a specific disease condition. Our results in healthy individuals also suggest that distinct qualities of breathlessness relate to different physiologic mechanisms underlying respiratory discomfort.

Key words: cluster analysis; descriptors of breathlessness; dyspnea; multidimensional scaling

Abbreviation: MDS = multidimensional scaling

Dyspnea is a term used to characterize the subjective experience of breathing discomfort that occurs in many conditions, and an awareness of a sensation is a component of all definitions of dyspnea, or breathlessness.1–4 As a sensory experience, dyspnea is frequently compared with the sensation of pain, which is seen largely as a multidimensional experience that varies along at least three factors or dimensions: sensory-discriminative, cognitive-evaluative, and affective-motivational.5,6 Clustering and multidimensional scaling (MDS) algorithms have uncovered and subsequently confirmed these dimensions of experience in patients and in healthy individuals.7–11 Additionally, clustering techniques have been used to study phrases or descriptors of breathlessness in patients seeking medical care for breathing discomfort to uncover the ways in which patients describe their “uncomfortable awareness of breathing.”4,12–15

The features (structures) of breathing discomfort in different patient groups were demonstrated initially by Simon and colleagues.14 They used cluster analysis to identify eight clusters of descriptors in 53
patients with shortness of breath, and reported that certain
statements (descriptors) of uncomfortable awareness of breathing were more likely to be
described by patients with certain conditions. For
example, patients with asthma selected “My breath
does not go out all the way,” “My breathing requires
effort,” and “My chest feels tight” as descriptors of
their breathlessness; patients with COPD chose “My
breathing requires effort” and “I feel a hunger for
more air” to characterize their experience of breath-
lessness. Elliot and colleagues examined 45
descriptors of breathing discomfort in 169 patients and
separated the descriptors into 12 groups (clusters) that
appeared to describe different aspects of breathing
discomfort. In a later study, evidence that pa-
tients with different cardiorespiratory conditions
experience distinct qualities of breathlessness was
gathered in a large sample of patients (n = 218) who
sought care for difficulty in breathing.

In a subset of those patients, descriptors selected by COPD
patients (n = 16) on two occasions approximately 1
week apart were compared to determine the reliability
of selections. The agreement for all descriptors was
79% (r = 0.82).

The perceived clinical value of uncovering features (structures) of breathing discomfort stems, to
date, from cluster solutions obtained in patients
asked to select from lists of descriptors those that
describe their “uncomfortable awareness of breathing” with activities. The groups of descriptors that
have emerged to represent different aspects of
breathing discomfort have never been shown to be
independent either of the presence of an underlying
pathophysiology or of a specific medical condition.
For example, the descriptor “I feel tight” is recur-
rently associated with asthma but only because pa-
tients with asthma—and not patients with other
medical conditions—generally select “I feel tight” as
a statement that applies to their “uncomfortable awareness of breathing.” It is possible, however, that
patients use phrases to describe their condition in
ways that are not easily interpretable by nonpatients,
and there is little reason to assume that the association
among descriptors in patients is the same as the
association among descriptors in healthy individuals.
Differences in the way groups of individuals use
words to describe their symptoms could have implica-
tions for inferring the health status of patients. For
example, suppose patients were to use phrases such
as “uncomfortable” and “in pain” interchangeably to
describe their symptoms on separate occasions be-
cause they perceive no difference (ie, no “distance”)
between the terms. If health-care providers, on the
other hand, were to picture a much larger concep-
tual distance between the two terms, they might
incorrectly infer their patients’ health status.

In the present study, we tested the hypothesis that
the descriptors of breathlessness represent distinct
and separable constructs, and predicted that the use
of descriptors of breathlessness by outpatients is the
same as their use by healthy individuals. Healthy
individuals rated the dissimilarity between pairs of
descriptors used previously by patients to communi-
cate the experience of dyspnea. Cluster outcomes
obtained in healthy individuals were compared with
those obtained previously in patients who com-
plained of breathing discomfort. In addition, we used
MDS techniques to analyze relationships among
descriptors in terms of the dimensions of subject
ratings. As a control condition, participants first
judged the dissimilarity between pairs of animals.

**Materials and Methods**

**Participants**

The participants were 48 men and 52 women (students,
faculty, and staff at the University of North Carolina Charlotte)
ranging in age between 18 and 65 years (mean, 27.9 ± 11.7
years). All participants were native English speakers. None had
prior familiarity with either the purposes or procedures of the
study. No incentives were offered for their participation except
that all students (n = 77) received extra credit in a psychology
course.

**Materials and Procedure**

Each participant completed a survey in about 30 min at a single
setting. In the first part of the survey, participants judged the
dissimilarity between pairs of animals created by the combina-
tion of six different animals (canary, chicken, dog, cat, cow, and
sheep). This condition was included to familiarize subjects with
the task and to make sure they were able to perform dissimilarity
ratings. Before the task, subjects were provided the following set
of written instructions:

“In this experiment you will practice making judgments of the
difference, or dissimilarity, between pairs of objects. Remember
that we will ask you to judge not how similar two things seem, but
how dissimilar, or different, two things seem. For each animal
pair you are to judge how dissimilar two animals are by using a
scale ranging from 0, which means no difference at all between
pairs, to 10, which means very much difference between pairs.
For each pair of animals you should write a number on the line
that is provided. On each trial, therefore, you will be presented
with a pair of animals. You should judge how dissimilar each pair
is by making your response on the line that follows each animal
pair.”

After participants read the instructions, they rated the dissim-
ilarity between 21 pairs of animals, the lower triangle of all
possible pairs including the diagonal (ie, each animal paired
with itself). The pairs were listed on a single sheet of paper. For each
participant, both the sequence of all possible pairs and the order
of animals within each pair were presented in random order.

Following this, participants judged the dissimilarity between
pairs of descriptors of breathlessness created by the combina-
tion of 15 different descriptors (Table 1). The set of descriptors was
the same as that examined previously in patients who com-
plained of breathing discomfort. Before the task, participants were
provided the following set of written instructions:
Table 1—Descriptors of Breathlessness

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>I feel that I am suffocating</td>
</tr>
<tr>
<td>2.</td>
<td>My chest feels tight</td>
</tr>
<tr>
<td>3.</td>
<td>My breathing is heavy</td>
</tr>
<tr>
<td>4.</td>
<td>I feel that I am smothering</td>
</tr>
<tr>
<td>5.</td>
<td>My breath does not go in all the way</td>
</tr>
<tr>
<td>6.</td>
<td>My breath does not go out all the way</td>
</tr>
<tr>
<td>7.</td>
<td>I feel that I am breathing more</td>
</tr>
<tr>
<td>8.</td>
<td>I feel that my breathing is rapid</td>
</tr>
<tr>
<td>9.</td>
<td>My breathing requires effort</td>
</tr>
<tr>
<td>10.</td>
<td>I cannot get enough air</td>
</tr>
<tr>
<td>11.</td>
<td>I feel a hunger for air</td>
</tr>
<tr>
<td>12.</td>
<td>My breathing is shallow</td>
</tr>
<tr>
<td>13.</td>
<td>I feel out of breath</td>
</tr>
<tr>
<td>14.</td>
<td>My chest is constricted</td>
</tr>
<tr>
<td>15.</td>
<td>My breathing requires work</td>
</tr>
</tbody>
</table>

“In this part of the experiment, you will be asked to judge how dissimilar descriptors of uncomfortable breathing sensations seem to you. In this case, you will judge two, or a pair of, descriptors used to characterize breathing sensations. After the second descriptor in each pair, you should write a number where it asks for a dissimilarity judgment. Like before, you are to judge how dissimilar, or different, the two descriptors seem by making a mark on the line using a scale ranging from 0, which means no difference at all between pairs, to 10, which means very much difference between pairs. On each trial then, you will be presented with a pair of descriptors of kinds of breathing sensations. You should judge how dissimilar each pair is by making your response on the line that follows each pair.”

After they read the instructions, they rated the dissimilarity between 120 pairs of descriptors, the lower triangle of all possible pairs including the diagonal (ie, each descriptor paired with itself). The pairs were listed on consecutive sheets of paper. For each participant, both the sequence of all possible pairs and the order of descriptors within each pair were listed in random order. After completion of the second judgment task, participants completed the third, and final, portion of the survey. Here, they first confirmed the absence of chronic disease and then provided their age, sex, and level of education. Next, they responded (yes or no) as to whether they experienced uncomfortable awareness of breathing with activities. Finally, participants rated their perceived level of understanding (knowledge) of the experience of shortness of breath in exercise, in asthma, in cystic fibrosis, and in congestive heart failure. For each condition, participants rated their “perceived familiarity” of shortness of breath as either “very familiar,” “somewhat familiar,” “somewhat unfamiliar,” or “very unfamiliar.”

Data Analysis

Mean dissimilarity judgments were computed for each unique pair of terms (or phrases) for both the animal and descriptor tasks, and were analyzed by cluster analysis and MDS. We performed these two complementary analyses to assess the degree of association among pairs of verbal stimuli. In primary analyses, mean dissimilarity judgments were computed using data provided by all participants (n = 100). In secondary analyses, mean judgments were computed for subgroups of subjects, and solutions obtained for each complementary pair of subgroups were compared. Subjects were divided into five dichotomous groups based on age (< or ≥ 30 years); sex (male or female); randomization; level of education (≤ or > 12 years); or, uncomfortable awareness of breathing with activities (yes or no).

Cluster Analysis: Cluster analysis was used to group terms or phrases according to their common properties. Cluster analysis is a set of statistical tools used to organize a collection of objects or experiences into fewer, meaningful categories. Like other techniques designed to simplify data by identifying a small number of underlying factors or dimensions, cluster analysis represents a largely descriptive set of techniques that operates with simple constraints: similar items are grouped together, and each item is placed in only one cluster. In most procedures, items are grouped together to minimize the variance within each cluster and to maximize the variance between clusters. We used the hierarchical average-linkage technique, which uses information about all pairs of distances to provide a visual representation (a dendrogram) of the successive links or connections among clusters made up of progressively increasing numbers of descriptors. In average clustering, each member of a cluster has a smaller average dissimilarity with other members of the same cluster than with members of any other cluster. Use of the average-linkage technique enabled direct comparisons with cluster analyses performed with patient data.

A technical problem with uncovering the underlying structure of proximity data involves the general lack of criteria for determining the optimum number of clusters (ie, a stopping rule). Generally, interpretations consistent with recurring clusters, and those that follow knowledge of or theory about underlying stimulus attributes, are the most satisfactory. Our solutions were influenced by the primary aims of the study—to compare clusters and their associated descriptors in healthy individuals with those obtained in patients. In addition, we compared the pattern of associations between clusters and particular disease conditions through reanalysis of patient data collected in the project by Mahler et al.

MDS: In our application, the MDS method solves for an optimal spatial configuration of verbal stimuli based on their rank order of dissimilarity and treats mean dissimilarity ratings as distances in a Euclidean space. The scaling procedure attempts to place objects (words) in this space along a minimum number of interpretable dimensions to best satisfy all the pair distances existing in the data matrix. Each point in the space is associated with a fixed, scaled location. We used Kruskal’s nonmetric monotonic algorithms to estimate each solution’s goodness of fit, or “stress.” A perfect fit among the distance measures is assumed when stress equals zero, although in most situations, a stress value of 0.05 indicates a good fit. Acceptable two-dimensional (stress = 0.003) and three-dimensional (stress = 0.046) solutions were obtained for the animal and descriptor tasks, respectively, and are presented in the following results section.

Results

Participant Characteristics

The mean age of the male (mean, 29.4 years) and female (mean, 26.6 years) participants was similar (t(98) = 1.19; p > 0.05). Comparable numbers of men and women (Table 2) were > 30 years old (χ² = 0.02; p > 0.05), and comparable numbers reported experiencing uncomfortable awareness of breathing with activities (χ² = 1.06; p > 0.05). On the other hand, more men than women in the sample had earned college degrees (χ² = 8.04; p < 0.05). Most participants (73%) were familiar with the ex-
experience of dyspnea in exercise, and most were unfamiliar with dyspnea as occurs in asthma (82%), in cystic fibrosis (95%), or in congestive heart failure (84%). Although the expressed familiarity with dyspnea as occurs in disease in a few subjects was most likely based on experiences with relatives, or was acquired in other similar ways, subjects were not asked to provide the exact source of their experiences.

Primary Analyses

Animal Ratings: Mean dissimilarity judgments ranged between 0.13 (dissimilarity between two cows) and 9.23 (dissimilarity between a canary and a cow). Mean judgments for the lower triangle of all possible pairs including the diagonal (ie, each animal paired with itself) are shown in Table 3. The cluster analysis grouped animals based on the mean estimates of dissimilarity. The first level of grouping indicated that dissimilarity judgments were related to animal size. This observation is represented as the highest level in Figure 1 where pairs of animals of similar size (sheep and cow, cat and dog, and chicken and canary) are linked. As clustering proceeded, mammals clustered together until, at the bottom of the tree, the set of items was exhausted.

The two-dimensional MDS analysis resulted in a nearly perfect solution (stress = 0.003) and is shown in Figure 2. The arrangement of points along the horizontal axis—ranging from birds to mammals—indicates that the location of animals in the space is related to the type (ie, class) of animal or, alternatively, to animal size. The arrangement of points along the vertical axis—distinguishing house from farm—indicates that the location of animals in the two-dimensional space is related to the usual habitat of the animal or, in a related way, to animal function. These clear results indicate that subjects were capable of judging dissimilarity in a consistent fashion for a set of well-known objects.

Table 2—Characteristics of Male and Female Participants

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Male (n = 48)</th>
<th>Female (n = 52)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 30 yr</td>
<td>32</td>
<td>34</td>
</tr>
<tr>
<td>≥ 30 yr</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 12 yr</td>
<td>31</td>
<td>46</td>
</tr>
<tr>
<td>&gt; 12 yr</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>Uncomfortable awareness of breathing with activities</td>
<td>28</td>
<td>25</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>20</td>
<td>27</td>
</tr>
</tbody>
</table>

*Data are presented as No. of subjects.

Table 3—Matrix of Mean (± SD) Dissimilarity Judgments (n = 100) for All Unique Pairs of Animals

<table>
<thead>
<tr>
<th>Animals</th>
<th>Canary</th>
<th>Chicken</th>
<th>Dog</th>
<th>Cat</th>
<th>Cow</th>
<th>Sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canary</td>
<td>0.14 ± 0.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken</td>
<td>4.79 ± 2.17</td>
<td>0.14 ± 0.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dog</td>
<td>8.75 ± 1.44</td>
<td>8.37 ± 1.72</td>
<td>0.16 ± 0.56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cat</td>
<td>8.39 ± 1.79</td>
<td>8.15 ± 1.94</td>
<td>4.91 ± 2.22</td>
<td>0.15 ± 0.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow</td>
<td>9.23 ± 1.15</td>
<td>8.32 ± 1.95</td>
<td>6.49 ± 2.18</td>
<td>7.20 ± 2.12</td>
<td>0.13 ± 0.51</td>
<td></td>
</tr>
<tr>
<td>Sheep</td>
<td>8.88 ± 1.45</td>
<td>8.23 ± 1.87</td>
<td>5.95 ± 2.46</td>
<td>6.70 ± 2.12</td>
<td>5.26 ± 2.2</td>
<td>0.15 ± 0.54</td>
</tr>
</tbody>
</table>
Descriptor Ratings: Mean dissimilarity judgments ranged between 0.00 (dissimilarity between each descriptor paired with itself) and 7.9 (dissimilarity between “My breathing is heavy” and “My breathing is shallow”).

Cluster Analysis: The dendrogram resulting from the cluster analysis based on mean dissimilarity ratings is presented in Figure 3. In this analysis, the successive links between increasingly similar descriptors, or sets of descriptors, are represented until all the descriptors (branches) are combined at the bottom of the tree. The horizontal dotted lines in Figure 3 represent the levels at which 8 and 10 groupings were formed through combinations of similar elements. The clusters, and associated descriptors of breathlessness, obtained in healthy individuals were compared with the 8 clusters reported in a study of 53 patients by Simon et al14 and with the 10 clusters reported in a study of 218 patients by Mahler et al.12

Comparisons among the eight clusters, and associated descriptors, obtained in the investigation by Mahler et al12 and those obtained from the 100 healthy individuals in the current study are presented in Table 5. Nine of the 10 clusters, and 11 of the 15 associated descriptors, were replicated. The primary differences between the two sets of outcomes revolve around the division of the cluster “Work” in patients to two clusters in the present sample (“Work” and “Out of Breath”), and—as in the previous comparison—the realignment of the descriptors “I feel that I am smothering” and “I feel that I am suffocating” from the cluster “Suffocating” in patients, to a more common cluster “Air Hunger” in healthy individuals.

There is real value in using descriptors of breathlessness to assist health-care providers in identifying or predicting a specific diagnosis, or in distinguishing among types of dyspnea in a patient with two or more diseases.4 We compared, therefore, the pattern and number of associations among specific clusters and particular pathophysiologic conditions through a reanalysis of patient data collected in the project by Mahler et al12 using the clusters, and their associated descriptors, obtained in the present study (Table 5). The criterion we used to determine whether a...
particular cluster was associated with an underlying condition was identical to that used previously.\textsuperscript{12,14} The number of times the descriptors within each cluster had been chosen by each of the 218 patients as among the “best three” that applied to their breathing difficulty was divided by the product of the number of descriptors in that cluster and the number of patients with that medical condition. A cluster met the criterion for association when this ratio was $> 0.25$.\textsuperscript{12,14} Comparisons between the relationships among clusters based on the dissimilarity ratings in the healthy individuals and the disease conditions represented among the 218 patients studied by Mahler et al\textsuperscript{12} are presented in Table 6. Seventeen of the 18 associations between clusters and disease conditions
were replicated. The exception between the two sets of outcomes is the lack of association between the cluster “Work” and deconditioning. Additionally, the cluster “Out of Breath” (which replaced the cluster “Suffocating” in the healthy individuals; Table 5) was associated with every condition except neuromuscular weakness; and the cluster “Air Hunger” (which along with “Suffocating” and “Shallow” was not associated with any condition in the original patient analyses) was associated with neuromuscular weakness.

MDS: The three-dimensional MDS analysis resulted in an acceptable solution (stress = 0.046) and is shown in Figures 4 and 5. In Figure 4, the arrangement of points along the horizontal axis (ie, Dimension 1) indicates that the location of descriptors in the space is related to “Depth and frequency of breathing,” ranging, right to left, from hindered or obstructed breathing (eg, “My chest is constricted”), to partial or incomplete breaths (eg, “My breath does not go in all the way” and “My breath does not go out all the way”), to increased levels of breathing (eg, “I feel that I am breathing more”). The arrangement of points along the vertical axis (ie, Dimension 2)—ranging from moderate (eg, “My breathing is shallow” and “My breath does not go out all the way”) to manifest experiences (eg, “I cannot get enough air” and “I feel that I am smothering”)—suggests that the location of descriptors in the two-dimensional space is related to “Perceived need or urge to breathe.”

Table 5—Comparison Between Clusters and Associated Descriptors Obtained in Patients (Mahler et al12) and Those Obtained in Healthy Individuals (n = 100)

<table>
<thead>
<tr>
<th>Clusters (n = 10) Proposed by Mahler et al12</th>
<th>Associated Descriptors</th>
<th>Comparative Clusters (n = 10) Obtained in Healthy Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid</td>
<td>I feel that my breathing is rapid</td>
<td>Rapid</td>
</tr>
<tr>
<td>Exhalation</td>
<td>My breath does not go out all the way</td>
<td>Exhalation</td>
</tr>
<tr>
<td>Shallow</td>
<td>My breathing is shallow</td>
<td>Shallow</td>
</tr>
<tr>
<td>Inhalation</td>
<td>My breath does not go in all the way</td>
<td>Inhalation</td>
</tr>
<tr>
<td>Tight</td>
<td>My chest feels tight</td>
<td>Tight</td>
</tr>
<tr>
<td>Heavy</td>
<td>My breathing is heavy</td>
<td>Heavy</td>
</tr>
<tr>
<td>More</td>
<td>I feel that I am breathing more</td>
<td>More</td>
</tr>
<tr>
<td>Work</td>
<td>My breathing requires effort</td>
<td>Work</td>
</tr>
<tr>
<td>Air hunger</td>
<td>I feel out of breath</td>
<td>Out of breath</td>
</tr>
<tr>
<td>I cannot get enough air in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel that I am smothering</td>
<td></td>
<td>Air hunger</td>
</tr>
<tr>
<td>I feel that I am suffocating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4—Comparison Between Clusters and Associated Descriptors Obtained in Patients (Simon et al14) and Those Obtained in Healthy Individuals (n = 100)

<table>
<thead>
<tr>
<th>Clusters (n = 8) Proposed by Simon et al14</th>
<th>Associated Descriptors</th>
<th>Comparative Clusters (n = 8) Obtained in Healthy Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid</td>
<td>I feel that my breathing is rapid</td>
<td>Rapid</td>
</tr>
<tr>
<td>Exhalation</td>
<td>My breath does not go out all the way</td>
<td>Exhalation</td>
</tr>
<tr>
<td>Shallow</td>
<td>My breathing is shallow</td>
<td>Shallow</td>
</tr>
<tr>
<td>Tight</td>
<td>My chest feels tight</td>
<td>Tight</td>
</tr>
<tr>
<td>Heavy</td>
<td>My breathing is heavy</td>
<td>Heavy</td>
</tr>
<tr>
<td>Work</td>
<td>My breathing requires effort</td>
<td>Work</td>
</tr>
<tr>
<td>Air hunger</td>
<td>I feel a hunger for air</td>
<td>Air hunger</td>
</tr>
<tr>
<td>I feel that I am smothering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel that I am suffocating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In Figure 5, the arrangement of points along the horizontal axis (ie, dimension 1) replicates the “Depth and frequency of breathing” axis described previously. The arrangement of points along the vertical axis (ie, dimension 3) indicates that the location of descriptors in the space is related to “Difficulty breathing and phase of respiration” by distinguishing inspiratory difficulties (eg, “My breathing is shallow” and “My breath does not go in all the way”) from expiratory difficulties (eg, “My breathing requires work” and “My breath does not go out all the way”).

Secondary Analyses

Composition of Subgroups: In secondary analyses, mean dissimilarity judgments were computed using data for subgroups of subjects, and solutions were obtained for each complementary pair of subgroups. Subjects were divided into pairs of groups based on age (< or ≥ 30 years); sex (male or female); randomization.
tion; level of education (≤ or > 12 years); or, uncomfortable awareness of breathing with activities (yes or no) (Table 2).

Animal Ratings: The cluster solutions obtained for each complementary pair of subgroups were indistinguishable from one another. The results of the two-dimensional MDS analyses for each of the 10 subgroups were virtually identical (stress = 0.00 to 0.031; mean, 0.005). The correlations between each complementary pair of subgroups for the fixed, scaled locations of each item obtained in the two-dimensional MDS solution ranged between 0.971 and 0.997 (p < 0.001).

Descriptor Ratings: We compared the cluster solutions obtained in the complementary pairs of groups when 10 groupings were formed through combinations of similar elements, or groups of elements. The clusters, and associated descriptors of breathlessness, were virtually identical between subgroups and exactly the same as the solution presented for the entire sample.

The results of the three-dimensional MDS analyses for each of the 10 subgroups were highly similar (stress = 0.047 to 0.068; mean, 0.059). The correlations between each complementary pair of subgroups for the fixed, scaled locations of each item obtained in the three-dimensional MDS solution ranged from 0.419 for levels of education and 0.442 for age (p < 0.05), to between 0.917 and 0.975 for sex, uncomfortable awareness of breathing with activities, and randomization (p < 0.001).

**Discussion**

We have provided evidence that cluster solutions for dissimilarity judgments between pairs of descriptors of breathlessness in healthy individuals are virtually identical to cluster solutions for the experience of breathing discomfort obtained previously in patients with a wide range of cardiopulmonary disorders. These results indicate that the use of descriptors of breathlessness by healthy individuals is the same as the use of descriptors by patients with cardiopulmonary disease. Moreover, we reconfirmed the pattern of relationships between certain clusters and disease conditions described previously by Mahler and colleagues. These analyses indicate further that the "distance" between pairs of descriptors in healthy individuals is similar to the "distance" between pairs of descriptors in patients who complain of dyspnea. Together, these findings allow us to affirm that the relations among descriptors of breathlessness obtained previously in patients are not simply dependent on either the presence of underlying pathophysiology or on a specific disease condition, but represent distinct and separable cognitive constructs.

Cluster solutions and MDS outcomes in healthy
individuals were largely independent of demographic variables such as age, sex, level of education, and the experience of uncomfortable awareness of breathing with activities. These latter results demonstrate that the conceptual distance between pairs of descriptors is independent of variation in common demographic variables. Such a conclusion would likely be strengthened by an assessment of the use of descriptors in a sample of individuals comprising a greater number of older (> 60 years) healthy individuals. In addition, our overall conclusions would likely have been further supported by formal assessment of lung function in the participants. Although from an epidemiologic perspective it would be highly unusual to see chronic obstructive lung disease, interstitial lung disease, or occult cardiac disorders in our participants, they were determined to be “healthy” only through self-report.

A limit to the interpretation of the similarity in the use of descriptors of breathlessness by healthy individuals and in the use of descriptors by patients with cardiopulmonary disease observed in previous studies relates to possible changes in knowledge about the symptom of dyspnea in the general population that may have occurred since the study by Simon et al.14 Although we have no specific data to address the concern, we believe it is unlikely that knowledge of dyspnea, per se, has changed significantly among the general public. For example, public education courses for cardiac disease have emphasized early recognition of cardiovascular symptoms and the variety of ways in which myocardial ischemia may become manifest (e.g., basic and advanced cardiac life support). Recent efforts to increase public awareness about asthma have focused on use of peak flowmeters, control of environmental triggers for asthma, and use of anti-inflammatory agents. Long-standing educational materials for COPD have largely been geared toward smoking cessation programs.

Cluster Analysis

Our applications demonstrate that methodologic advances in the study of the language of dyspnea mirror advances in the study of the language of pain, in that healthy individuals rate the dissimilarity among phrases in a manner comparable to that of patients. Such applications may be used with increasing confidence to articulate the subjective experience of breathing discomfort. Current data suggest that between 8 and 10 categories of sensory experience serve to adequately differentiate among various states of breathing discomfort. Subsequent decisions to recommend an exact number of clusters to guide clinical judgments will likely depend on the perceived importance of the pattern and number of associations between specific clusters and particular pathophysiologic conditions. Schwartzstein4 noted that current patterns of relationships between clusters and patient conditions include evidence of multiplicity (each condition is characterized by more than one cluster), uniqueness (each condition is associated with a unique set of clusters), and sharing (some clusters are associated with more than one condition). It is likely that work will continue to elucidate the precise set of phrases and combinations that best reveal patient experiences of breathing discomfort.18 Future applications of clustering algorithms to explore not only the sensory but also the cognitive-evaluative and affective-motivational nature of descriptors used to characterize breathing discomfort may affect the number of clusters in any final solution.5,19,20

The likelihood that breathing discomfort varies along a limited number of factors or dimensions has theoretical and clinical implications.4,12,13 Information about different kinds of sensory experiences may contribute to our understanding of the mechanisms of dyspnea.12,21 The prospective use of descriptors of breathlessness may assist health-care providers in identifying or predicting a specific diagnosis, or in distinguishing among types of dyspnea in a patient with two or more diseases. Additionally, qualitative changes in the experience or intensity of shortness of breath may relate to the symptomatic benefit of a therapeutic intervention.7,22 On the other hand, although we reinforce confidence in the common understanding of the problem between patient and health-care provider, it is not yet clear the extent to which such common understanding may serve to improve patient outcomes.

MDS

We articulated three dimensions of experience of breathing discomfort through application of MDS algorithms to dissimilarity ratings. These results complement several decades of research involving both patients and healthy individuals that have underscored the role of abnormalities in both the mechanics of breathing and in the drive to breathe in accounting for the experience of dyspnea. For example, Comroe,2 in summing up his observations of a 1965 symposium, concluded that there may be as many as five or six types or grades of breathlessness: awareness of increased ventilation, shortness of breath, hindered breathing, suffocation, and the sensation at the breaking point of breath-holding. Guz23 described four different types of respiratory sensations: breath-holding sensations, irritation of the tracheobronchial tree, obstructed breathing, and the inability to get in enough air. Campbell and Guz1
concluded that among the elemental sensations of chest tightness or irritation, excessive ventilation, excessive frequency of breathing, and difficulty in the act of breathing, the latter experience was consonant with classic dyspnea. The three dimensions of breathing discomfort uncovered with MDS—“Depth and frequency of breathing,” “Perceived need, or urge, to breathe,” and “Difficulty breathing and phase of respiration”—converge on the recurrent sensory experiences emphasized by these and other researchers. More importantly, the MDS solution for the descriptors we used suggests a modest total number of attributes (three) of uncomfortable awareness of breathing.

Our interpretation of the first dimension uncovered through MDS—“Depth and frequency of breathing”—relates primarily to the most influential model for characterizing the basis of breathing discomfort. More than 30 years ago, Campbell and Howell suggested that the perception of breathlessness resulted from a perceived mismatch between the ventilation demanded and the ventilation achieved. In its early formulations, conscious perception of an imbalance between ventilatory demand and ventilatory supply—between the respiratory cost of breathing and the achieved benefit of ventilation—was envisaged in all instances that could give rise to the sensation of breathing difficulty. Another model of ventilatory inappropriateness is presented in work by Lougheed et al. They conclude that the perception of breathlessness in airflow limitation “encompasses the conscious awareness of disproportionate inspiratory effort for a given ventilatory output.”

Our interpretation of the location of the descriptors along the first dimension is influenced by models of ventilatory inappropriateness and related abnormalities in the mechanics of breathing. We labeled the dimension “Depth and frequency of breathing” because ventilation is defined as the product of tidal volume and respiratory rate. Descriptors related to obstructed or restricted breathing (eg, “My chest is constricted”) are located at one end of the continuum and reflect the greatest degree of perceived inappropriateness (the greatest cost for a given level of output). The perceived imbalance to breathing is presumed to be reduced near the middle of the continuum. In other words, the perceived cost of breathing is diminished when only one phase of breathing appears affected (ie, when “My breath does not go in all the way” or “My breath does not go out all the way”). Descriptors located at the other end of the continuum (“I feel that I am breathing more”) are presumed to reflect a more favorable ratio, a perceived gain in output for any given cost of breathing.

We connect the second dimension, “Perceived need, or urge, to breathe,” with the construct air hunger, which is evident in conditions that result in an increased drive to breathe caused by exercise, congestive heart failure, and pregnancy. Acute abnormalities in blood gas valves that are evident in many disease states also give rise to increases in the perceived need or urge to breathe. The sense of air hunger is not necessarily dependent on increases in ventilation but seems to result from involuntary increases in stimulation, as occurs, for example, during an prolonged breath hold. We interpret the arrangement of descriptors along dimension 2—ranging from “I feel a hunger for air” and “I cannot get enough air” to “My breathing is shallow” and “My breath does not go out all the way” —as reflecting variations in the perceived intensity of need to breathe (from manifest to moderate). In this analysis, the perceived drive to breathe is hypothesized to represent a particular state of respiratory awareness. Variations in ventilatory state (dimension 2) are thought to interact with subsequent perceptions of ventilatory inappropriateness (dimension 1).

The third dimension—“Difficulty breathing and phase of respiration”—suggests that qualitatively different sensory experiences of ventilatory inappropriateness (dimension 1) arise from difficulty breathing in as compared with difficulty breathing out (dimension 3).

Previous work suggests that there are unique sensory experiences arising from inspiratory difficulty compared with those arising from expiratory difficulty. A majority of patients report that breathlessness occurs not only while breathing in but also while breathing out. Patients with asthma, for example, complain mostly of inspiratory difficulty during acute bronchoconstriction, but breathlessness in asthma is described as involving both inspiratory and expiratory difficulty. In healthy individuals, “Airflow direction” (inspiration or expiration) was one dimension of experience that emerged in a previous MDS study designed to uncover the organization of sensory experiences elicited by various breathing maneuvers (eg, inspirating or expiring through both small and large resistances).

In the present study, the descriptors associated with “Inspiratory difficulty” (“My breathing is shallow” and “My breath does not go in all the way”) are readily discernible, but some descriptors associated with “Expiratory difficulty” (eg, “My breathing requires work” and “My breathing requires effort”) seem less clear (Fig 5). We interpret the descriptors related to the increased work or effort of breathing as referring to increases in the intention or purposefulness of breathing out, which is normally accomplished through passive recoil of the lung. The pair
of descriptors used previously by Lougheed et al.\textsuperscript{25} and O’Donnell and colleagues\textsuperscript{26}—“Breathing in requires more effort” and “Breathing out requires more effort”—highlights the value of recognizing separate difficulties associated with inspiration and with expiration.

In summary, we have shown that the features or structures of breathing discomfort uncovered in patients are not simply dependent on the presence of underlying pathophysiology or on a specific disease condition. Our data support conclusions that breathlessness in each condition results from a different composite of sensations.\textsuperscript{4} Three attributes of breathing discomfort were revealed through application of MDS algorithms to dissimilarity ratings: disturbances in the mechanics of breathing; alterations in the drive to breathe; and difficulty breathing and phase of respiration. In conclusion, our results in healthy individuals support the contention that the association of different clusters with different disease states reflects distinct qualities of breathlessness and possibly different physiologic mechanisms underlying respiratory discomfort.

\textbf{References}