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Respiratory Variability and Psychological Well-Being in Schoolchildren

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Among the relations between respiration and psychological state, associations with respiratory variability have been contradictory. In this study, respiration was measured noninvasively in 162 children with a mean age of 11 years (from 9 to 13). They completed a battery of psychological tests. Structural Equation Modeling (SEM or LISREL) revealed a model that fit the data well (χ^2 = 88.201, *df* = 79, *p* = .224). In this model, respiratory variability was positively related to anger-in and negatively to negative fear of failure and neurotic complaints. Respiration rate was positively related to positive fear of failure, and duty cycle was positively related to the latent variable of negative affect. Variability in resting time components of respiration was higher among children with less fear of failure and fewer complaints. Therefore, respiratory variability need not necessarily be a sign of psychological dysfunctions, and interventions should not always impose a fixed breathing pattern.

Keywords: *respiratory variability; positive affect; negative affect; respiratory time components*

Most of the research on psychological correlates of respiration has been executed with adults rather than with children and adolescents. Nevertheless, it may be worthwhile to focus also on the social-emotional state of the children, where children with negative affectivity (neuroticism, anxious disposition, anger, and depression) (Watson & Tellegen, 1985) have a general tendency to react negatively to stressful

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situations (Roeser, van der Wolf, & Strobel, 2001) often accompanied by psychosomatic disorders (including specific patterns of respiration) and feelings of depression. Youngsters may also have positive dispositional affectivity (feelings of well-being, extraversion, energy, persistence, and enthusiasm) that corresponds with feeling competent, being motivated, being involved in school life, and showing fewer psychosomatic problems (Gaillard, 1996).

In the research on childhood, however, little attention has been paid to the interconnections between social-emotional state and psychophysiological indicators during this important life period. These interconnections could provide useful information to school-based mental health practitioners seeking to improve their school-based prevention and intervention efforts that serve both educational and mental-health-related goals simultaneously (Adelman & Taylor, 1998). Research in this area is needed so that more progress can be made to understand patterns of functioning and pathways of development of children and young adolescents who are particularly vulnerable during these critical years (Jessor, 1993).

Although the psychological correlates of respiration have been studied extensively, the field of respiratory psychophysiology has emerged only recently (Wientjes & Grossman, 1998). The respiratory variables studied consist mostly of frequency and volume parameters of breathing and their derivates. These parameters respond to changes in psychic state and may serve as indicators of the state of mind. Also, changes in respiration influence the psychological state (Boiten, Frijda, & Wientjes, 1994; Morgan, 1983). A relatively neglected parameter is respiratory variability. Boiten et al. (1983) devoted only a few paragraphs to it. *Variability* refers to the individual breath-by-breath variation in time or volume components of the respiratory cycle. Relatively few experimental studies focus on emotional implications of respiratory variability, and the results are inconclusive. Pronounced irregularity was found in patients with anxiety disorders (Stevenson & Ripley, 1952). Hormbrey, Jacobi, Patil, and Saunders (1988) found abnormally wide fluctuations in baseline for inspiratory time, expiratory time, and end-tidal CO_2 in symptomatic hyperventilators compared to "normals" and asthmatic patients. Martinez et al. (1996) performed 24-hour ambulatory monitoring of respiration and showed significantly greater standard deviation in minute ventilation during sleep in patients with panic disorder compared to normal volunteers. Comparing patients with panic disorder and generalized anxiety disorder with control participants, Wilhelm, Trabert, and Roth (2001) studied respiration during a 30-minute period of quiet sitting. Both patients' groups had greater instability in respiratory parameters than the control groups, whereas instability in tidal volume was highest in patients with panic disorder.

Based on results like these, it is generally assumed that regularity of breathing is normal and healthy. This is confirmed by the effect of experimental modification of breathing. "Paced breathing," breathing at a fixed and relatively low rate, has been shown to reduce arousal (Cappo & Holmes, 1984; McCaul, Solomon, & Holmes, 1979; Sakakibara & Hayano, 1996). Thus, a regular, slow, and/or abdominal breathing pattern is taken as a positive characteristic and a desirable goal of treatments like breathing retraining, which helps to reduce complaints and arousal (Bonn, Readhead, & Timmons, 1984; DeGuire, Gevirtz, Hawkinson, & Dixon, 1996; Grossman, de Swart, & Defares, 1985; Ley, 1991).

By contrast, variability of a biological function is in itself a natural and healthy characteristic. To maintain a steady state of the organism, feedback loops are continuously active, resulting in cyclical variations of a given parameter around a desirable set-point. For instance, it has been amply demonstrated—and by now widely accepted—that heart-rate variability is positive and that high variability is associated with a healthy system (Giardino, Lehrer, & Feldman, 2002). Donaldson (1992) studied respiratory behavior in a time-series measurement of normal, resting breathing of 8 adults. He found irregularity of all parameters: lowest for CO_2, highest for expiratory time, and intermediate for total cycle time. He concluded that the chaotic nature of resting human respiration allows for fast and flexible responses to sudden changes, which strengthens the stability of the system as a whole.

In an experimental study of induced emotion, Boiten (1998) found that the induction of a pleasant emotional state resulted in increased respiratory variability. Breath-to-breath variability was lower for expiratory time during a suspenseful video clip and significantly higher for tidal volume, minute ventilation, and inspiratory flow rate during amusing and funny video clips. His data suggested that much of the variability in breathing is because of the induction of positive affect. The intrinsic variable nature of healthy breathing is at odds with paced-breathing treatment but is in agreement with a more sophisticated practice of breathing therapy, as in the methods of Middendorf, Proskauer, and van Dixhoorn (Buchholz, 1994; Proskauer, 1968; van Dixhoorn, 1995). In these methods, breathing is used not only as a means for changing one's state but also as feedback information to the person on his actual state. Thus, the so-called indicator role of breathing is being respected. The value of such increased sensory feedback of breathing awareness has been experimentally tested in a clinical trial in myocardial infarction patients by van Dixhoorn and Duivenvoorden (1999). The results showed a positive effect on physical and psychological parameters in the short run and a reduction of cardiac events in the long run.

In this study, respiratory parameters were investigated in normal school children and related to a battery of psychological tests. The main research question is, What is the relationship of positive and negative affect to respiratory parameters and in particular to respiratory variability?

METHOD

PROCEDURE

Data were collected concerning respiration characteristics and personality traits by well-trained interviewers (see Authors' note). The respiration data were collected individually by a capnograph to measure hyperventilation (end-tidal CO_2level) and by a respiration registration device (Respicon 1) to measure body movements during inhalation and exhalation. A respiration-measurement session took about 15 min for each participant—about 1 min at the capnograph for 10 exhalations pretest, 5 min at the Respicon 1, and 1 min again at the capnograph for 10 exhalations posttest; the remaining time was needed for a correct installation of the measurement devices. The standardized personality questionnaire about the psychological aspects (anger, anxiety, lack of perseverance, motivation, self-criticism, and so forth) was administered in the classroom and took about 80 min.

PARTICIPANTS

The participants in our study were 161 children from the seventh and eighth grades of five elementary schools in two satellite towns (Purmerend and Hillegom) in the Netherlands. The ages varied from 9 years old to 13 years old with a mean of 11.3 years (*SD* = .82). The group consisted of 73 boys and 88 girls. Elementary grade seven had 78 children participating in our study and grade eight had 84 children. The schools were situated in middle-class neighborhoods in which most of the children were White.

INSTRUMENTS

The measurement instrument for the respiration characteristics investigated in this study is the Respicon 1 for body movements. The Respicon 1 is an electronic biofeedback system that consists of a portable box with a keyboard, a display, and a sensor (a respiration registration girdle) powered by a battery supply. The elastic registration girdle, put around the breast, enables the researcher to obtain an accurate measurement of respiration characteristics of a participant. The following respiratory parameters were measured: number of respiration cycles during 5 minutes (N_RESP), mean respiration time (Ttot), mean inspiration time (Ti), mean expiration time (Tex), mean expiration pause time (Tp), inhalation time as percentage of total cycle time (Ti/Ttot), pause time as percentage of total cycle time (Tp/Ttot), the fluctuation rate (*SD*) of the respiration time (*SD*Ttot), the fluctuation rate of the inspiration time (*SD*Ti), the fluctuation rate of the expiration time (*SD*Tex), the fluctuation rate of the expiration pause (*SD*p).

ASSESSMENT OF PERSONALITY ASPECTS

Assessment of the personality aspects took place via a number of affect variables such as perseverance, inadequacy, motivation, self-critical attitude, anger, fear of failure, neurotic lability, anxiety, and so on. They were administered in the order described in the text. To assess perseverance, a subset of 25 items was drawn from the Dutch Personality Questionnaire (NPVJ). Each item of this subset asks children to mark on a Likert-type scale how positively they assess their own task-orientation in school affairs, their adjustment to the demands of the school, their motivation to respond to high school expectancies, their willingness to keep an appointment, and their ability to keep everything on an even keel.

Inadequacy was administered by a subset of 28 items of the NPVJ that measure symptoms associated with vague physical complaints, depressed mood, vague fears, and feelings of inadequacy. Each item of the NPVJ asks children to indicate on a 3-point Likert-type scale whether they have ever experienced a particular problem or symptom. Next, the answer categories of the separate items were recoded so that the total score of the two subscales could be interpreted as a measure of perseverance and inadequacy as formulated by Luteijn, van Dijk, and van der Ploeg (1989). The internal consistency of the scales was good.

Measures of state anxiety and trait anxiety were administered with the State Trait Inventory for Children, drawn from the work of Bakker, van Wieringen, van der Ploeg, and Spielberger (1989). The state anxiety scale consists of 20 items (on a 3-point Likert-type scale). The children were asked to respond to the items in terms of their present feelings of psychological well-being. The disposition scale consisted of 20 items with respect to general feelings of well-being.

The N-scale, which was used to measure neurotic lability manifested in psycho-neurotic complaints and instability, was adapted from the Amsterdam Biographic Questionnaire for Children from van Dijl and Wilde (1982). We also administered Hermans's Achievement-Motivation Test (1983) to assess motivation, positive fear of failure (the fear of failure that leads to a better functioning), and negative fear of failure (the fear of failing, stuck in unstructured task-situations). These subscales consist of 3-point Likert-type scale items that are recoded in such a way that a high score on a corresponding subscale indicates high motivation, strong positive fear of failure, and strong negative fear of failure respectively. Former research indicated that the internal consistency of the scale was good.

The van der Ploeg, Defares, and Spielberger Self-Analysis Scale (1982) was administered to measure anger-in and anger-out. This questionnaire gives an indication for internalized anger (4 items) and externalized anger (4 items).

Finally, a self-critical test attitude (vs. self-defensive test attitude) was measured on a T-scale, which was adapted from the Amsterdam Biographic Questionnaire (van Dijl & Wilde, 1982).

RESULTS

RESPIRATION VARIABLES

Means and standard deviations of the respiration variables for 73 boys and 88 girls are presented in Table 1. Except for the inhalation variables Ti/Ttot and *SD*Ti, there were no significant differences between boys and girls; significant differences on the inhalation variables were remarkably small. As this is just a group of ordinary children, all the variables behave in a normal way. Ti is shorter than Tex, and the standard deviations of the respiratory cycles (.61 and .66, respectively) do not reveal inordinate oscillations.

To keep the model of the respiratory variables and the affect variables manageable, a principal component analysis was used to reduce the respiratory variables to a smaller number of kernel variables (components). The results in Table 2 show that the 3 components explain 91% of the total variance, which is extraordinarily high in social science research. Without substantial loss of information, the 3 components may, therefore, be used further on instead of the original variables.

Each of the components has a clear interpretation. Because the correlation of the first component is .963 with Ttot (and this variable correlates highly positive with Tex and highly negative with N_RESP, of course), there is nothing lost by taking this first component to be equal to Ttot (the mean individual total cycle time or respiration rate). A similar conclusion may be drawn for components 2 and 3. Given the nearly perfect correlations with *SD*Ttot (.950) and Ti/Ttot (.943), the respective variables *SD*Ttot (variability of Ttot) and Ti/Ttot (duty

TABLE 1
Means and Standard Deviations of Respiratory Variables

	Gender			
	Boys		*Girls*	
	Mean	SD	*Mean*	SD
N_RESP	94.23	16.68	95.44	16.44
Ti	1.35	.31	1.28	.28
Tex	1.96	.37	1.98	.43
Ttot	3.30	.61	3.27	.66
Ti/Ttot	.42*	.04	.40*	.04
Tp/Ttot	.29	.08	.29	.06
*SD*Ti	.42*	.24	.35*	.14
*SD*Tex	.70	.34	.66	.31
*SD*p	.61	.30	.55	.22
*SD*Ttot	.88	.42	.80	.30

$*p < .05$.

cycle) may represent the corresponding components. The strong negative correlation of Tp/Ttot with the duty cycle component (Ti/Ttot), which at first sight may seem strange, is merely an artifact because the proportion Tp/Ttot will practically always become smaller as the proportion Ti/Ttot becomes larger; together with Tex/Ttot they must add up to 1.

PSYCHOLOGICAL AFFECT VARIABLES

Table 3 presents results on positive affect variables and negative affect variables documented for boys and girls. Differences on the positive affect variables STAMINA (perseverance) and MOTIVATION (achievement motivation) are small, but girls are more self-critical than boys. On the negative affect variables, boys seem to show more anger than girls, and they have more positive fear of failure. Girls, on the other hand, seem to be more anxious and uncertain, and they are more prone to neurotic tendencies than boys.

Principal component analysis to reduce the number of variables leads to 3 components that explain 66% of the total variance of the affect variables. This solution is acceptable in all respects, although it

TABLE 2
Principal Component Analysis of Respiratory Variables After Rotation

	Component		
Variable	*1*	*2*	*3*
N_RESP	–.958	–.206	–.011
Ti	.843	.174	.473
Tex	.907	.277	–.278
Ttot	**.963**	.255	.041
Ti/Ttot	–.051	.005	**.943**
Tp/Ttot	–.085	.178	–.820
*SD*Ti	.310	.831	.274
*SD*Tex	.191	.912	–.170
*SD*p	.163	.865	–.360
*SD*Ttot	.242	**.950**	–.019
Variance explained	36.03%	34.19%	21.00%

NOTE: Numbers in bold indicate highest loading.

is less elegant than the respiratory analysis. The 3 components have a clear interpretation. The first component may be called NEG AFFECT (negative affect) and the second component POS AFFECT (positive affect). Without doubt, the third component has to be interpreted as anger, but the number of constituting variables may be too small to get an identifiable structural equation model when anger is used as a latent variable in such a model. Therefore, ANGER-IN and ANGER-OUT will be related to the positive and negative affect components that can be used without problems. The number of constituting variables satisfies the 3-indicator rule (Bollen, 1989, p. 247), so the negative affect component and the positive one can be used as latent variables in the model.

THE RELATIONSHIP BETWEEN RESPIRATION VARIABLES AND AFFECT VARIABLES

To study the relationship between the respiration variables and the affect variables, a structural equation model will be proposed in Figure 1 with the 3 respiration variables—respiration rate (Ttot), variabil-

TABLE 3
Means and Standard Deviations of the Psychological Affect Variables

	Gender			
	Boys		*Girls*	
	Mean	SD	*Mean*	SD
STAMINA	37.48	7.06	37.44	8.15
MOTIVATION	17.64	5.88	16.74	6.04
SELF-CRITICAL	5.84*	2.59	6.94*	3.14 b < g
ANGER-IN	8.95*	6.26	7.05*	5.55 b > g
ANGER-OUT	4.55**	2.53	3.13**	2.21 b > g
POSITIVE FEAR OF FAILURE	11.58**	4.29	8.97**	3.96 b > g
NEGATIVE FEAR OF FAILURE	5.78**	3.74	7.99**	3.09 b < g
INADEQUACY	13.93*	11.16	17.65*	10.44 b < g
NEUROTIC LABILITY	9.30**	5.27	11.64**	5.81 b < g
NEUROTIC COMPLAINTS	6.52**	3.98	8.69**	4.08 b < g
ANXIETY TRAIT	28.77**	6.47	32.33**	6.36 b < g
ANXIETY STATE	26.44**	3.85	29.19**	4.28 b < g

*$p < .05$. **$p < .01$.

ity (*SD*Ttot), and duty cycle (Ti/Ttot)—as independent variables and the latent variables—POS AFFECT and NEG AFFECT—as dependent variables. In contrast with the model in which the role of the dependent variables and independent were reversed, this model fits the data satisfactorily ($\chi^2 = 88.20$ with $df = 79$ and $p = .224$; RMSEA = .027).

All direct relations shown in the model are statistically significant (Table 5), except for the correlations between duty cycle (Ti/Tot) and respiration rate (Ttot) and between duty cycle (Ti/Tot) and variability (*SD*Ttot). The path coefficients for the path from POS AFFECT to STAMINA and for the path from NEG AFFECT to ANXIET-S are not significant either, as they are fixed at 1.00 for the purpose of identification. The model is less refined than may have been expected. Ideally, the independent respiration variables would have been related to the two latent affect variables and, thus, be indirectly related to the observed indicators. As the model in Figure 1 and the estimates in Table 5 show, this is not the case in practice. In fact, only Ti/Ttot shows

TABLE 4
Principal Component Analysis of the Psychological Affect Variables

	Component		
	1	*2*	*3*
STAMINA	–.161	**.838**	–.057
MOTIVATION	–.134	**.702**	.135
SELF-CRITICAL	–.045	**.829**	–.088
ANGER-IN	–.141	.201	**.892**
ANGER-OUT	–.077	–.228	**.890**
POSITIVE FEAR OF FAILURE (POSFAIL)	**–.608**	.121	.259
NEGATIVE FEAR OF FAILURE (NEGFAIL)	**.720**	–.072	–.217
INADEQUACY (INADEQU)	**.822**	–.125	–.113
NEUROTIC LABILITY (NLABILE)	**.852**	–.175	–.061
NEUROTIC OMPLAINTS (NEURCOM)	**.755**	–.143	–.100
ANXIETY TRAIT (ANXIET-S)	**.866**	–.083	.035
ANXIETY STATE (ANXIET-T)	**.637**	.019	.104
Variance explained	34.04%	17.23%	14.75%

NOTE: Numbers in bold indicate high loading.

a direct negative relation to NEG AFFECT. As the duty cycle increases, the negative affect variable decreases. The other respiration variables link up directly to the observed affect variables. Furthermore, it should be noted that none of the respiration variables relates directly to a positive affect variable. At the utmost, a relatively small indirect effect could exist from Ti/Ttot via the correlated error terms e20 and e21 of the latent affect variables ($-.173 \times -.325 = .056$). Had this correlation between the error terms as usual been caused by a common factor, then the indirect effect on POS AFFECT would also have been shrunken to zero.

The respiration rate (Ttot) merely relates to positive fear of failure (POSFAIL). In other words, as the mean individual respiration rate is higher, the positive fear of failure will be greater (and pupils will get somewhat better results). The respiration variability (*SD*Ttot) shows a positive relation with anger-in and a negative relation with neurotic complaints (neurcom) and negative fear of failure (NEGFAIL). As the fluctuation of the respiration rate is higher, the restrained feelings of anger are greater in general, whereas the neurotic complaints and the negative fear of failure will be smaller. The correlations between the

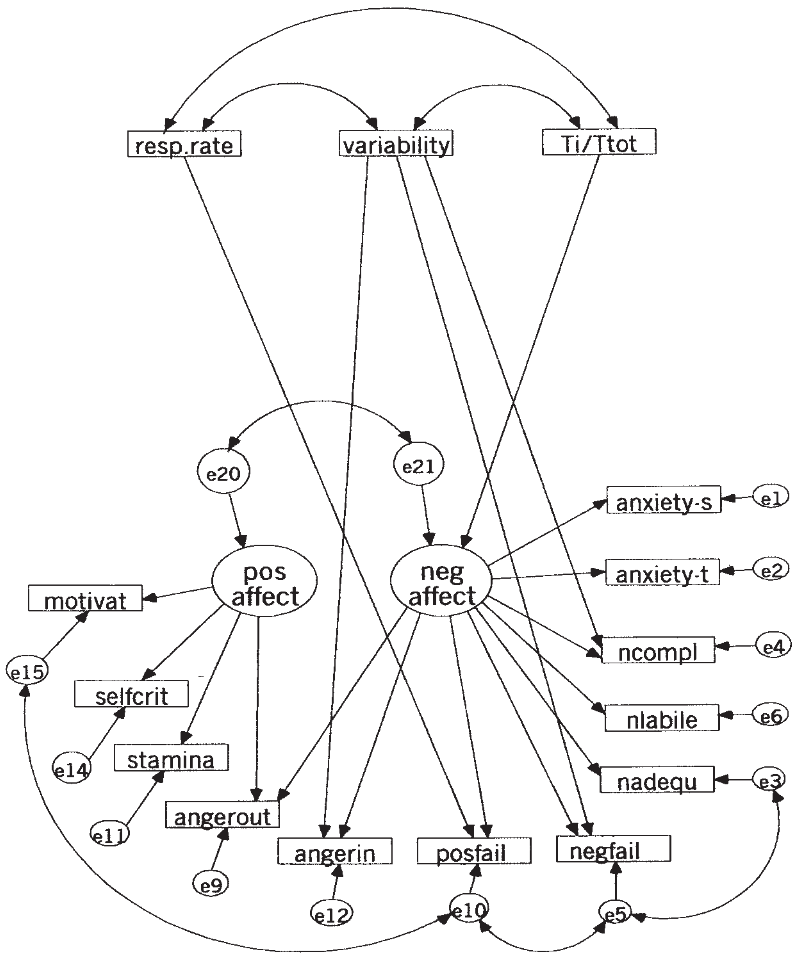

Figure 1. Structural equation model of the relationship between respiration variables and affect variables.

error terms of the observed affect variables leading to a better fit are quite plausible as well.

The error term of motivation (e15), or, more precisely, achievement motivation, is related positively with the error term of positive fear of failure (e10). In turn, this relates negatively to the error term of nega-

TABLE 5
Unstandardized Structural Equation Model Parameter Estimates for the Relationship Between Respiration Variables and Affect Variables

Path From	*Path To*	*Unstandardized Path Coefficients*	SE	t *Value*
Ti/Ttot	NEG AFFECT	–9.52	4.52	–2.10
VARIABILITY	ANGER-IN	1.89	0.87	2.17*
VARIABILITY	NEURCOM	–1.48	0.66	–2.22*
VARIABILITY	NEGFAIL	–1.31	0.54	–2.43*
POS AFFECT	MOTIVATION	0.51	0.08	5.98**
POS AFFECT	SELF-CRITICAL	0.34	0.04	7.39**
POS AFFECT	STAMINA	1.00		
POS AFFECT	ANGER-OUT	–0.16	0.02	–5.52**
NEG AFFECT	INADEQU	4.67	0.76	6.14**
NEG AFFECT	NLABILE	2.54	0.40	6.23**
NEG AFFECT	ANXIET-S	1.00		
NEG AFFECT	ANXIET-T	2.78	0.45	6.11**
NEG AFFECT	POSFAIL	–1.05	0.21	–4.81**
NEG AFFECT	NEGFAIL	1.13	0.20	5.44**
NEG AFFECT	NEURCOM	1.44	0.25	5.69**
NEG AFFECT	ANGER-IN	–0.73	0.25	–2.85**
NEG AFFECT	ANGER-OUT	–0.32	0.11	–2.89**

*$p < .05$. **$p < .01$.

tive fear of failure (e15), and this relates negatively to the error term of inadequacy (e3). Likewise, the error terms of ANGER-IN and ANGER-OUT show correlation.

DISCUSSION

The main findings of this study are twofold. First, respiratory variability appears to be an independent characteristic of breathing. It can be operationalized as the standard deviation of various measurements of time components: total cycle time, inhalation time, exhalation time, or exhalation pause time. Second, the variability in time components is, in schoolchildren, positively related to restrained feelings of anger and, more important, negatively related to neurotic complaints and negative fear of failure. Thus, young children with low scores on negative psychological traits have a higher respiratory variability than children with high negative scores. This result supports the idea that respiratory variability is a sign of healthy normal breathing.

Most research demonstrates the opposite, that high variability and irregularity of breathing is a sign of psychopathology, such as fear or panic disorder. Boiten et al. (1994) theorized that "irregularities ensue when neural influences on respiratory control processes are highly incompatible, as may be the case during emotional and behavioural states that involve conflicting, or incongruous components." For instance, Wilhelm et al., 2001, compared variability during "quiet sitting" in patients with panic disorder, general anxiety disorders, and normal controls. Quiet sitting in a laboratory with electrodes attached, however, may feel quite unsettling for patients with panic and anxiety. They may feel forced to stay quiet and not to move, whereas they actually would prefer to run away. The increased incidence of deep sighs, which contributes to the variability, may reflect the urge to run, which is constrained. This conflict could lead to increased variability. We would need data to know how the participants actually felt at the moment that measurements were taken.

The idea of conflicting states would mean that variability is high because there are two dominant and opposing factors that guide respiratory timing. In that case, the frequency pattern that is shown by frequency analysis would be a rather simple power spectrum with two peaks, for instance a relatively fast and shallow breathing coupled to incidents of deep sighs (Paul Lehrer, personal communication, March 31, 2001). However, calculation of standard deviation, as was done in this and other studies, indicates variability but does not show the lack of complexity of the power spectrum. The natural variability of a healthy biological function would result in a more complex power spectrum because a large number of factors influence respiration (Donaldson, 1992; Giardino, Lehrer, and Feldman, 2002; Hugelin, 1986). This variability is healthy because it allows respiration to respond adequately to all kinds of sudden changes in the environment. In participants who feel pleasant and relaxed, respiration is not dominated by one or two single factors and may assume it is normal chaotic behavior. The difference between standard deviation and frequency analysis could explain that variability is associated with both positive and negative affect.

These ideas have important implications for the practice of voluntary regulation of breathing. Research shows that controlled breathing reduces respiratory irregularity and improves a negative psychological state. Voluntary, paced breathing may therefore serve as an antidote to the effects of conflicts or stressors, and according to Umezawa (2001), it is widely practiced as such. On the other hand, a steady, regular breathing pattern does not seem to be a model for healthy, normal respiration. Thus, it should not be presented as ideal, and it should not be the therapeutic goal to practice steady, regular breathing at all times.

It could even be useful to improve responsiveness and variability of breathing, for instance, in case of low variability, when respiration is probably dominated by a single factor. This requires a more sophisticated form of breathing therapy in which the subject learns to observe and become familiar with the responses of breathing to various mental and physical influences. Instead of a controlling mental attitude toward one's breathing, subjects need to acquire an allowing attitude (van Dixhoorn, 1995). For instance, such an approach has been useful for lung cancer patients to help them deal with the presence of shortness of breath (Bredin, et al., 1999).

The relationship found between respiration and mental state also suggests relevance for the work of school-based mental health professionals in their continuing effort to redress problems in children and adolescents. Switching to a physiological point of reference by focusing on the enhancement of the students' respiratory functions in relation to psychological well-being may provide a means to link up with educators—and vice versa—in their attempt to obtain optimal development for all members of the student body.

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