

## REACTION TIME FOLLOWING YOGA BELLOWS-TYPE BREATHING AND BREATH AWARENESS<sup>1</sup>

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*Summary.*—The reaction time (RT) was assessed in two groups of healthy males, yoga group ( $M$  age = 29.0 yr.) and non-yoga or control group ( $M$  age = 29.0 yr.), with 35 participants each. The yoga group had an average experience of 6 months, while the control group was yoga-naïve. The yoga group was assessed in two sessions, (i) *bhastrika pranayama* or bellows breathing and (ii) breath awareness, while the control group had a single control session. The two experimental sessions, one with each type of breathing, and the control session consisted of pre- (5 min.), during (18 min.), and post-session epochs (5 min.). Assessments were made in the pre- and post-session epochs using a Multi-Operational Apparatus for Reaction Time. Following 18 min. of *bhastrika pranayama* there was a statistically significant reduction in number of anticipatory responses compared to before the practice. This suggests that the immediate effect of *bhastrika pranayama* is to inhibit unnecessary responding to stimuli.

Voluntary breath regulation is a part of specific yoga techniques called *pranayamas* (Taimini, 1986). Breath regulation is given particular emphasis in yoga, as regulating the breath is believed to help regulate the mental state (Swami Muktibodhananda, 1985). Three weeks of slow yoga breathing [called *savitri pranayama*, Cohen's  $d = 1.43$  for visual reaction time (VRT); 2.13 for auditory reaction time (ART)] and fast yoga breathing (*bhastrika pranayama*, Cohen's  $d = 0.15$  for VRT; 2.68 for ART) reduced simple reaction times (VRT, ART) in both groups of practitioners, though this was not statistically significant (Madanmohan, Udupa, Bhavanani, Vijayalakshmi, & Surendiran, 2005). The acute effect of *bhastrika pranayama* on reaction time was assessed in a single group of 22 school boys, 13 to 16 years of age, who had received training in yoga for three months (Bhavanani, Madanmohan, & Udupa, 2003). Following nine rounds of *bhastrika pranayama*, there was a statistically significant reduction in both VRT (Cohen's  $d = 2.81$ ) and ART = 3.15. The large effect sizes could be due to a practice effect, as there was no control group assessed similarly without any intervention. The acute effects of nine rounds of *bhastrika pranayama* were also studied in 34 adolescents with intellectual disability (age range 14 to 16 years). All of them had been practicing yoga once a week for

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at least 2 years (Bhavanani, Ramanathan, & Kt, 2012). This single-group study also showed a decrease in VRT (Cohen's  $d = 2.50$ ) and ART (Cohen's  $d = 2.38$ ). In this study, too, a practice effect cannot be ruled out in the absence of a control group. The authors speculate that in these two studies, voluntary breath regulation associated with yoga breathing techniques or *pranayamas* increase the availability of subcortical and cortical attentional resources, making it possible to perform the reaction time test more quickly.

Spontaneous and controlled breathing were found to have different effects on the reaction time, based on the difference in the allocation of attentional resources to breathing (Gallego, Perruchet, & Camus, 1991). For example, reaction time was reported to be slower during inspiration in a previous study (Buchsbbaum, & Callaway, 1965). This was attributed to inhibition, mediated via the vagus and the nucleus of the *tractus solitarius*. However, a subsequent study reported shorter reaction times during inspiration (Beh & Nix-James, 1974), which was attributed to muscle involvement, with increased muscle tension in diaphragmatic and thoracic muscles believed to facilitate muscle responding in general. A study assessing the relation between voluntarily controlled breathing and performance on a simple reaction time test showed an increase in reaction time when participants partly focused their attentional resources on breathing (Gallego, et al., 1991). The authors found that the increase in reaction time was greatest at the onset of exhalation and they attributed this to a shift from agonist to antagonist activity of the diaphragm and change in activity of the cortical and sub-cortical areas involved.

Some of the studies cited above reported shortened reaction times associated with voluntarily regulated breathing. It is supported by the fact that other voluntarily regulated yoga breathing practices (*pranayamas*) have been shown to improve performance in letter-cancellation tasks, which require sustained attention and the ability to shift attention (Telles, Raghuraj, Maharana, & Nagendra, 2007; Telles, Raghuraj, Arankalle, & Naveen, 2008). Also, high frequency yoga breathing improved the performance in the P300 Event-related Potential task with an auditory oddball paradigm (Joshi & Telles, 2009). In this auditory oddball paradigm, participants were asked to attend to high frequency auditory stimuli, interspersed randomly among low-pitched auditory stimuli (Polich, 1999). It is possible that the attentional resources required for these tasks are not otherwise engaged (are more available) during voluntarily regulated yoga breathing, as yoga trains participants in awareness with relaxation (Taijini, 1986). This may help yoga practitioners to perform attentional tasks with fewer attentional resources. There is a report that mentions a connection between attention and anticipation, stating that anticipation facil-

itates attention to specific stimuli (van Damme, Crombez, & Eccleston, 2004). In this sense, yoga may also help accuracy when responding to a cue that anticipates the actual signal.

Also, it is to be noted that in all the studies cited above the tasks or reaction time tests were given before or after yoga breathing, but not during breathing. Studies of the acute effects of *bhastrika pranayama* on reaction time are limited by the absence of a control or comparison group. The present study was designed to assess the acute effects of *bhastrika pranayama* compared to breath awareness practiced in the same individuals on another day, and both groups compared to a non-yoga control group. Breath awareness was selected as a comparison for *bhastrika pranayama* because breath awareness is a part of all *pranayama* practices. Having breath awareness as a separate session would help to separate (or subtract) the effects of *bhastrika pranayama* (which has breath awareness as a part of it) from breath awareness alone. The present study was conducted to test the following hypotheses:

*Hypothesis 1.* *Bhastrika pranayama* would improve the performance in a reaction time task.

*Hypothesis 2.* Breath awareness and the control intervention would have no effect on the task performance.

## METHOD

### *Participants*

There were two groups (yoga and control) of thirty-five healthy, male volunteers each, participating in the trial. The yoga group ( $M$  age = 29.0 yr.,  $SD$  = 6.4, range = 20–40) were assessed in two sessions. The control group (average age  $M$  = 29.0 yr.,  $SD$  = 6.6) was assessed in a single session. The yoga group had been practicing yoga postures (*asanas*) and yoga breathing (*pranayama*) for an average of six months, while the control group was naïve to yoga. Following the practice of yoga there can be two types of effects: acute or short-term effects and longitudinal effects seen over a period of time. In the present study, the participants had already been practicing yoga for six months. This would have altered their baselines, and differences from the control group might be expected as a longitudinal effect of the practice. Any changes seen after practicing the two yoga breathing techniques for 18 min. would be examples of acute effects. All participants were healthy and were not taking any medication. They were found to be right-hand dominant (except for a single person in the control group), based on a standard questionnaire for hand dominance (Oldfield, 1971). An institutional research ethics committee approved the project. Participants' signed informed consent was obtained.

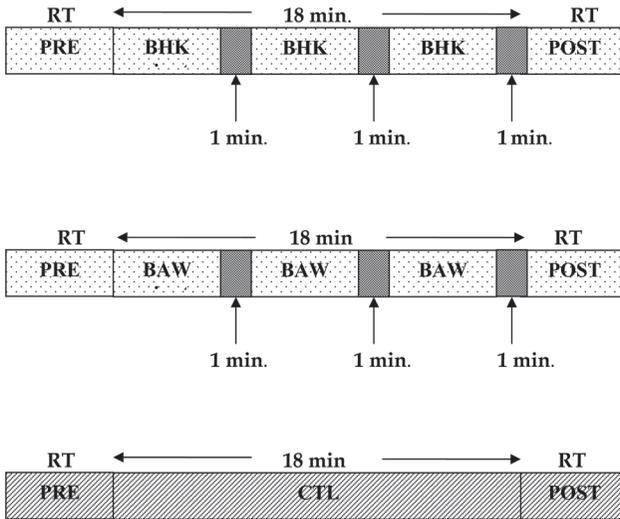


FIG. 1. Schematic representation of the study design. Dotted boxes: yoga group tested on two days, BHK = *Bhastrika pranayama*, BAW = breath awareness; hatched boxes: control group (CTL) tested once; gray boxes: one-minute duration between practice epochs.

### Design

As described above, the yoga group was assessed on two separate days at the same time of day. On one day they practiced *bhastrika pranayama* and on another day they practiced breath awareness. Each practice was for 18 min. The two breathing techniques were practiced on separate days with at least 24 hours between them. Half the yoga group had the *bhastrika pranayama* session on the first day and the breath awareness on the second day, while the reverse was true for the remaining half. The control group was assessed at the beginning and end of an 18-min. period without any intervention to study the re-test effect. A schematic presentation of the design is given in Fig. 1.

### Assessment Procedure

The Multi-Operational Apparatus for Reaction Time (MOART: Lafayette Instrument Company, Model no. 35600, Lafayette, IN.) was used along with PsymCon, Model no. 35500 to carry out a Simple Reaction Time (RT) test. The apparatus has three, colored LED (light-emitting diode) stimuli. These lights can be set as red, green, or orange. For the present study the stimuli were of two types. The green light was used to signify "Give a response (Go)." This assessed RT in seconds. The red light signified "Do not give a response (No Go)." The orange light was used as a cue or indicator and indicated that the participants were to expect a stimulus. The

participant was asked to press a button with the index finger of the preferred hand as quickly as possible in response to the green light, after the presentation of the orange warning stimulus. An incorrect response was pressing the button in response to a red light after the warning stimulus. An anticipatory response was pressing the button after the warning stimulus, but before the green or red light appeared. There were 5 trials for each assessment. Each participant had 4 assessments (pre-*Bhastrika*, post-*Bhastrika*, pre-Breath awareness, post-Breath awareness). The basis for fixing the number of trials at five was that after 4 sessions, participants had been previously found to maintain their motivation and attention for a maximum of 5 trials.

The following variables were measured: (i) time taken to respond to a green light (RT, sec.), (ii) number of correct responses to the green light, (iii) number of correct responses to the red light, and (iv) number of anticipatory (hence inaccurate) responses.

#### *Interventions*

As already described, the yoga group had two separate, counterbalanced interventions on different days. Each intervention was for 18 min. The two interventions were (i) yoga bellows-type breathing or *bhastrika pranayama* and (ii) breath awareness.

*Bhastrika pranayama*.—This breathing practice involves active inhalation and slow exhalation, with a rate of approximately 12 breaths per minute (Swami Ramdev, 2009). Participants practiced *bhastrika* as three, 5-min. intervals, with 1-min. breaks in between. Five min. has been observed to be the maximum duration in which participants can practice maintaining the breath rate within the expected range. The 1-min. breaks helped participants in this process. Also, based on the authors' observations and reports of practitioners, 18 min. total was selected as an optimal duration for the practitioner to carry out the practice without feeling fatigue or boredom. Throughout the practice, the participants adopted a cross-legged position, keeping their spine erect and neck aligned. They were also requested to keep their eyes closed throughout the practice and be aware of their breath.

*Breath awareness*.—In the breath awareness session, the participants were asked to feel the flow of air passing through the nasal passages. During this practice the participants adopted a cross legged position keeping their spine erect and neck aligned. They were also requested to keep their eyes closed throughout the practice.

*Control*.—The control group sat in a comfortable position with their eyes closed for 18 min. The reason for giving the control group no activity was to study the reaction time on retesting after no intervention to

see whether there was a re-test or practice effect. However, it would have been ideal to have another control group engaged in an activity as vigorous as *bhastrika pranayama*. The fact that this study does not have such a control group is a limitation.

#### *Data Analysis*

Statistical analysis was done using SPSS (Version 18.0). The analysis was a repeated-measures analysis of variance (ANOVA) in which there were two within-subjects factors. These are Session (*bhastrika pranayama*, breath awareness) and State (pre- and post-session). The second type of analysis was a paired *t* test for pre- versus post-session data collected from the control group. There were five Trials during which green and red lights appeared randomly (three of one color and two of the other). *Post hoc* tests with a Bonferroni adjustment were performed for within-groups, pre-post comparisons.

#### RESULTS

In the repeated-measures ANOVA, there was no significant difference between Sessions or interaction between Sessions  $\times$  States for any of the four variables. The difference between States was also not significant, though there was a trend of significance between States for anticipatory responses at the one-tailed level [ $p = .084$  (1-tailed)]. Based on this trend, a pre-post *post hoc* analysis with Bonferroni adjustment was conducted and a significant decrease in anticipatory responses was found ( $p = .04$ ).

Group mean values and standard deviations are presented in Table 1. The *df*, *MS*, *F*, *p*, and partial eta squared values are given in Table 2.

Paired *t*-test comparisons of pre-post means for the control group were conducted. Group mean values, standard deviations, *t*, *df*, *p*, and Cohen's *d* are reported in Table 3.

#### DISCUSSION

The immediate effect of 18 min. of *bhastrika pranayama* was to reduce the number of anticipatory responses in the reaction-time test. Breath awareness and the control session had no effect.

Anticipation of the arrival time of the stimulus allows participants to prepare to respond sufficiently early to respond coincidentally with the event (Schmidt, 1968). Anticipation is influenced by several factors such as (i) receptor anticipation and (ii) perceptual anticipation. Receptor anticipation is the performer's ability to make a decision on how long it will take an event to occur (Poulton, 1957). Other studies showed that receptor anticipation is present when participants can preview events such as stimulus presentation (Poulton, 1963). This leads to a decrease or absence of a lag in responding. In the present study, participants were not given

TABLE 1  
VARIABLES IN THE REACTION TIME ON THE GO-NO GO TASK

Measure and State	Bhastrika Session ( <i>n</i> = 35)		Breath Awareness Session ( <i>n</i> = 35)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
RT to "Go," sec.				
Pre-test	0.42	0.25	0.41	0.20
Post-test	0.41	0.13	0.40	0.14
Comparison (Pre-Post)	<i>p</i> = .55		<i>p</i> = .87	
No. of correct responses to "Go"				
Pre-test	2.34	1.11	2.57	0.92
Post-test	2.60	1.00	2.69	1.10
Comparison (Pre-Post)	<i>p</i> = .36		<i>p</i> = .65	
No. of correct responses to "No Go"				
Pre-test	2.40	1.22	2.11	1.02
Post-test	2.30	0.99	2.06	1.11
Comparison (Pre-Post)	<i>p</i> = .68		<i>p</i> = .80	
No. of (incorrect) anticipatory responses				
Pre-test	0.11	0.32	0.09	0.28
Post-test	0.00	0.00*	0.06	0.34
Comparison (Pre-Post)	<i>p</i> = .04		<i>p</i> = .71	

Note.—Values are group means  $\pm$  *SD* with percentage changes. Comparisons were pre- and post-test session means within-groups (*bhastrika pranayama* and breath awareness). \**p* < .05, repeated-measures ANOVA, with Bonferroni adjustment.

a preview of the stimuli, hence this kind of anticipatory response would not be helpful. Perceptual anticipation occurs when the presentation of stimuli is regular (Schmidt, 1968). In the present study, since the warning stimuli were delivered at a pre-determined rate, temporal anticipation may have helped participants respond, but this was true for all sessions: *bhastrika pranayama* and breath awareness, as well as the control session.

The reduction in the number of anticipatory responses following *bhastrika pranayama* could be related to several factors. Cholinergic connections in the *nucleus basalis*, located in the basal forebrain, are known to be important for attention. Muir, Everitt, and Robbins (1995) investigated the cholinergic specificity of basal forebrain lesions on disruption of attentional performance, using various pharmacological agents in rats. The 5-Ht3 receptor antagonist Ondansetron was effective in reducing premature responding in both control and lesioned animals, suggesting the importance of other neurotransmitters in addition to acetylcholine. The results

TABLE 2  
 DETAILS OF FOUR REPEATED-MEASURES ANALYSES OF VARIANCE

Variable	Source	<i>df</i>	MS	<i>F</i>	<i>p</i>	$\eta_p^2$	95%CI
RT to "Go," sec.	Sessions	1, 34	0.002	0.04	.84	.001	-.07, .11
	States	1, 34	0.008	0.24	.63	.007	-.05, .08
	Sessions $\times$ States	1, 34	0.003	0.22	.65	.006	-.07, .11
No. of correct responses to "Go"	Sessions	1, 34	0.860	0.81	.38	.023	-.51, .20
	States	1, 34	1.210	1.14	.29	.032	-.54, .17
	Sessions $\times$ States	1, 34	0.180	0.13	.72	.004	-.76, .31
No. of correct responses to "No Go"	Sessions	1, 34	2.310	1.74	.20	.049	-.14, .65
	States	1, 34	0.260	0.26	.61	.008	-.25, .43
	Sessions $\times$ States	1, 34	0.030	0.02	.88	.001	-.28, .85
No. of (incorrect) anticipatory responses	Sessions	1, 34	0.010	0.11	.74	.003	-.10, .07
	States	1, 34	0.180	1.98	.17	.055	-.03, .18
	Sessions $\times$ States	1, 34	0.060	1.00	.32	.029	-.10, .16

also suggested that disinhibition and accuracy of responses are possibly mediated by different pathways.

The findings of earlier studies (Gallego, *et al.*, 1991), which reported a delayed response to stimuli when participants were practicing voluntarily regulated breathing, are different from the present results, in which there was no change in response time. The difference could be related to the use of a warning signal in the present study. A warning stimulus is believed to reorient attentional resources toward the stimulus after the warning stimulus is heard, hence reducing reaction time (Blinkov, & Nikandrov, 1985).

The reduction in anticipatory responses following *bhastrika pranayama* is consistent with slowing down and reduced impulsivity following yoga practice described in traditional texts (Taimini, 1986). The decreased reaction time after *bhastrika pranayama* reported in earlier studies (Bhavanani, *et al.*, 2003; Bhavanani, *et al.*, 2012) was not found in the present study. This could be related to differences in the duration of practice (18 min. in the

TABLE 3  
 COMPARISON *T* TESTS FOR CONTROL GROUP

Variable	Pre-session		Post-session		<i>t</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>				
RT to "Go," sec.	0.49	0.18	0.50	0.21	-0.21	34	.83	-0.03
No. of correct responses to "Go"	3.29	0.83	3.23	1.09	0.29	34	.78	0.07
No. of correct responses to "No Go"	1.37	0.73	1.60	1.01	-1.39	34	.17	-0.31
No. of (incorrect) anticipatory responses	0.11	0.32	0.06	0.24	1.00	34	.32	0.15

present study and nine rounds of *mukh bhastrika* in the two earlier studies), or differences in experience (six months in the present study, compared to three months and yoga training once a week for more than three years in the previous studies) (Bhavanani, *et al.*, 2003; Bhavanani, *et al.*, 2012). The studies mentioned above also lacked a control group, making it difficult to rule out a practice effect. In this study the absence of change after the breath awareness session suggests that this practice may have no effect on inhibiting early responses or on responding to stimuli. Also, since the decrease in anticipatory responses following *bhastrika* was the only significant change out of 12 comparisons, with a small magnitude of change, it is possibly due to chance.

The main limitation of the study was that participants were not randomized into the three groups. Instead, the experimental group had two experimental sessions while the non-yoga group had one control session. In addition, the control group was not given any intervention, which is an inadequate control for a vigorous practice like *bhastrika pranayama*.

Despite these limitations, the present study suggests a role for *bhastrika pranayama* in reducing impulsivity and inhibiting unnecessary responses, which has potential practical applications.

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