Effect of Bhramari Pranayama on response inhibition: Evidence from the stop signal task

Sasidharan K Rajesh, Judu V Ilavarasu, Thaiyar M Srinivasan[1]

Department of Psychology, [1]Division of Yoga and Physical Sciences, Swami Vivekananda Yoga Anusandhana Samsthana, Kempegowda Nagar, Bengaluru, Karnataka, India

Address for correspondence: Mr. Sasidharan K Rajesh,
#19 Eknath Bhavan, No. 19, Gavipuram Circle, Kempgowda Nagar, Bengaluru - 560 019, Karnataka, India.
E-mail: rajesheskay@svyasa.org

ABSTRACT

Context: Response inhibition is a key executive control processes. An inability to inhibit inappropriate actions has been linked to a large range of neurologic and neuropsychiatric disorders.

Aims: Examine the effect of Bhramari Pranayama (Bhpr) on response inhibition in healthy individuals.

Settings and Design: Thirty-one male students age ranged from 19-31 years from a residential Yoga University, Bengaluru, India were recruited for this study. We used a randomized self as control within-subjects design. Participants were counterbalanced randomly into two different experimental conditions (Bhpr and deep breathing (DB)).

Materials and Methods: Response inhibition has been measured using a standard tool Stop Signal Task (SST). Each session lasted for 50 min with 10 min for the experimental conditions, preceded and followed by 20 min of assessment. The primary outcome measure was stop signal reaction time (SSRT), an estimate of the subject's capacity for inhibiting prepotent motor responses. Additional measures of interest were the probability of responding on stop signal trials, P (r | s) and mean RT to go stimuli.

Results: The mean probability of responding on stop signal trials (p (r | s)) during Bhpr and DB are close to 50%, indicating reliable SSRT. Paired sample *t*-tests showed a significant decrease (P = 0.024) in SSRT after Bhpr session, while the DB group did not show any significant change. Further, *t*-tests show that the go RT increased significantly after Bhpr (P = 0.007) and no other changes/differences were observed.

Conclusions: Bhpr enhanced response inhibition and cognitive control in nonclinical participants.

Key words: Bhramari; response inhibition; stop signal; yoga

INTRODUCTION

Adaptive functioning of behavior on the basis of feedback from the environmental requirements is an important characteristic of executive control. Response inhibition is the hallmark of executive function. It refers to the ability to inhibit inappropriate or irrelevant responses according to dynamic change in environment.[1] Response inhibition deficits have been linked to several psychopathological disorders.[2,3] The Stop Signal Task (SST) has proved to be a useful tool for the study of response inhibition in cognitive psychology, cognitive neuroscience, and psychopathology.[1] In SST, subjects act upon a go reaction time (RT) task. On a random selection of the trials (*stop signal trials*), a stop signal is presented, instructing them to withhold their go responses.[4] The ability to stop ongoing motor responses in a split second is a vital element of response control and flexibility that relies on frontal-subcortical network.[5] The stop paradigm is based on the race model where response execution races with the inhibitory process to determine whether a response is inhibited.[6] Further stop signal paradigm allows a sensitive estimate of inhibitory control known as the stop signal RT (SSRT), which reflects the time taken to internally suppress a response.[7] Furthermore, previous studies have shown medication for the treatment of attention deficit hyperactivity disorder (ADHD) enhanced SSRT in healthy volunteers.[8,9] To our knowledge, there is no study to date using this paradigm in yoga based research.

Yoga in its original form consisted of a system of ethical, psychological, and physical practices; although of ancient origin, it transcends cultures and languages.[10] Yoga lays emphasis on manipulation of breath movement (Pranayama), which contributes to a positive neurophysiologic response.[11] Yogic breathing technique called Bhramari Pranayama (Bhpr), involves producing a vibrating constant pitch sound emulating the buzzing of female bumble bee. The term Bhramari is a Sanskrit word meaning a female bee. In the Bhramari breathing technique, a humming sound resembling that of a female bee is produced. In this Pranayama, one produces a low pitched humming audible sound resembling the sound of a female bee as long as possible, during exhalation. EEG paroxysmal gamma waves were measured during approximately 20 breathing episode of Bhpr in eight subjects. The result shows an increased theta range activity, which is similar to results obtained with other meditation techniques.[12] Further, Bhpr as a therapy shows significantly reduced irritability, depression, and anxiety associated with tinnitus.[13] However, the effect of Bhpr on cognitive function has not been reported. In this study, we examine the effect of yogic breathing Bhpr on SST in healthy individuals.

MATERIALS AND METHODS

Subjects

Thirty-four undergraduate and graduate male students from a residential Yoga University, Bengaluru, India were recruited for this study. The final sample comprised 31 volunteers, because the data for three subjects were excluded due to failure of software. Participants' age ranged from 19 to 31 years with a mean age of 23.90 years (standard deviation (SD) =3.48). All reported having a normal or corrected vision and normal hearing. Females were excluded because of reported varying SST during phases of the menstrual cycle.[14] Participants were free from medication, smoking, alcohol consumption, and cardiorespiratory ailments by self-report. Since the handedness effects are not known, all subjects selected were right handed only. The experience of subjects practicing breathing techniques ranges from 6 months–5 years. The approval of the Institutional Ethics Committee was obtained and informed consent was collected. Participants received no monetary compensation for their participation.

Design and procedure

This was a randomized self as control within-subjects design. Participants were counterbalanced randomly into two different experimental conditions (Bhpr and deep breathing (DB)). Each session was on a different day. Half of the subject's undergone Bhpr session the first day and DB on the next day. For remaining half the order of the sessions

reversed. Subjects were counterbalanced to either one of the conditions, to wash out any possible learning effect. The time of day was kept constant for both sessions for an individual (6 am-8 am). Each session lasted for 50 min. The SST was recorded before and after the trial conditions. All subjects had undergone orientation in the experimental conditions (Bhpr and DB) for 15 days before the actual assessment. All subjects received a practice session 1 day prior to the experimental sessions in order to familiarize them with the SST and procedures. During the practice trails, experimenter shows the task on a laptop screen. Volunteers then undertook brief practice, until it was evident to the experimenter that the volunteer was responding appropriately. The experiment was conducted individually in a room under normal fluorescent lighting with a laptop in the research lab. Care was taken that during the experiment no external distractions or noises were present.

SST

The stimuli were presented on a laptop using STOP-IT, which is a free-to-use SST program.[7] Participants were seated approximately at 50 cm from the screen. The primary task is to perform a two-choice RT task in which subjects had to react as quickly and accurately as possible to discriminate between a square and a circle stimulus. The primary task stimulus followed by fixation sign (+) is presented in the center of the computer screen, in white, on a black background. The subject responds with 'Z' (for square) and '/' (for circle) on a keyboard with the left and right index finger, respectively. On no-signal trials (go task), only the primary task stimulus is presented. On stop-signal trials (Stop Task), an auditory 'stop signal' beep is presented at a variable delay (stop signal delay, SSD) following the go stimulus. Subjects are instructed to inhibit their responses on the trials with a stop signal beep. Tasks were presented randomly: Go task (75%) and stop task (25%). SSD is initially set at 250 ms and is adjusted continuously with dynamically tracking procedure, dependent upon the performance of the participant. Successful inhibitions resulted in an increase of the SSD by 50 ms, whereas failed inhibitions resulted in a reduction of the SSD by 50 ms. This procedure ensured that on average each participant in each session had a probability of successful inhibition approaching 50%.[7] A total of 392 trials were presented, divided over six blocks of 64 trials, lasting 3 min each. Subjects had waited for 10 s between blocks before they start the next block. The primary outcome measure is SSRT, an estimate of the subject's capacity for inhibiting prepotent motor responses. SSRT was calculated by subtracting mean stop signal delay from mean RT to go stimuli (go RT). Additional measures of interest are the probability of responding on stop signal trials, p (r | s) and Go RT.

Table 1: Bhramari and deep breathing: Mean and standard deviations

	Deep breathing		Bhramari pranayama	
	Pre	Post	Pre	Post
p (r|s)(%)	48.58±1.93	49.68±1.78	48.96±1.77	49.47±3.38
SSRT (ms)	239.44±30.59	237.35±38.40	243.75±40.16	232.67±43.81*
Go RT (ms)	733.88±170.89	751.81±182.16	701.67±184.10	732.24±193.40**

p (r\|s) = Mean probability of responding on stop-signal trials, SSRT = Mean stop-signal reaction time, Go RT = Mean reaction time on no-signal trials. *$*P<0.05$, ***$P<0.01$, *t* test for paired data comparing "pre" with respective "post" values

Experimental conditions

Subjects sat on a comfortable cushion on the floor of the experimental room, in a crossed leg posture keeping the spine erect, with eyes closed condition. On experimental session (Bhpr), after a deep inhalation, participant exhale strictly through the nasal airways, emulating the buzzing of bumblebees with a constant pitch. On control session (DB), the subjects assumed the Bhpr position, but did not produce the humming sound. Instead, they attempted to manipulate the respiratory rhythm by deep inhalation and exhalation.[12] Both the sessions were of 10 min in duration. Each subject performed approximately an average of 20 inhalations and exhalations per session.

RESULTS

Statistical analysis was carried out using Statistical Package for Social Sciences (SPSS) version 10.0. Table 1 shows the means of the SSRT and go RT and also the *p* (r | s). The mean probability of responding on stop-signal trials (*p* (r | s)) during Bhpr and DB are close to 50%, indicating that the dynamic tracking algorithm worked well in both sessions and produced a reliable SSRT. The data for SSRT and go RT were found to be normally distributed and difference between the means of the two PRE sessions was not significant. Paired sample *t*-tests showed a significant decrease ($P = 0.024$) in SSRT after Bhpr session, while the DP group did not show any significant change [Table 1]. The means in the post session were not significantly different, but the Bhpr group showed a notable lower value. Further, *t*-tests show that the Go RT increased significantly after Bhpr ($P = 0.007$) and no other changes/differences were observed.

DISCUSSION

In the present study, we have evaluated the immediate effect of Bhpr on SST. There was a significant reduction in SSRT, suggesting that the practice results in enhanced response inhibition.[1] Further, subject slow down the go responses, indicating subject made a proactive response strategy to achieve a balance between competing goals, suggesting a flexible cognitive control.[15]

As per our knowledge, there is no previous report specific to BhPr on cognitive function for comparison. We found that, enhancement of inhibitory control is consistent with previous behavioral studies on single dose administration of atomoxetine[8] and methylphenidate[9] in healthy volunteers. Atomoxetine and methylphenidate are widely used stimulant medication for the treatment of ADHD. The mechanism underlying the enhancement is not known. Dynamics of electroencephalogram (EEG) theta activity correspond to executive control demands across different sources of cognitive interference.[16] Theta power enhancement relates to the recruitment of cognitive control. Earlier study has shown resonating and repetitive effects of humming bee sound in the Bhpr breathing technique, increased theta activity.[12] We hypothesize that improvement in response inhibition may be due to enhanced theta activity. Further, it is possible to use this breathing technique as an adjunct for the management of ADHD. More studies are required for the use of this technique in clinical cases.

The study is limited by the small sample size, and the lasting effect of intervention was not assessed. Future studies should incorporate various assessment methods to capture changes while performing the task and intervention to understand underlying mechanism.

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REFERENCES

1. Verbruggen F, Logan GD. Response inhibition in the stop-signal paradigm. Trends Cogn Sci 2008;12:418-24.

2. Enticott PG, Ogloff JR, Bradshaw JL. Response inhibition and impulsivity in schizophrenia. Psychiatry Res 2008;157:251-4.

3. Aron AR, Poldrack RA. The cognitive neuroscience of response inhibition: Relevance for genetic research in attention-deficit/hyperactivity disorder. Biol Psychiatry 2005;57:1285-92.

4. Logan GD, Cowan WB, Davis KA. On the ability to inhibit simple and choice reaction time responses: A model and a method. J Exp Psychol Hum Percept Perform 1984;10:276-91.

5. Aron AR, Behrens TE, Smith S, Frank MJ, Poldrack RA. Triangulating a cognitive control network using diffusion-weighted magnetic resonance imaging (MRI) and functional MRI. J Neurosci 2007;27:3743-52.

6. Band GP, van der Molen MW, Logan GD. Horse-race model simulations of the stop-signal procedure. Acta Psychol (Amst) 2003;112:105-42.

7. Verbruggen F, Logan GD, Stevens MA. STOP-IT: Windows executable software for the stop-signal paradigm. Behav Res Methods 2008;40:479-83.

8. Chamberlain SR, Hampshire A, Muller U, Rubia K, Del Campo N, Craig K,

et al. Atomoxetine modulates right inferior frontal activation during inhibitory control: A pharmacological functional magnetic resonance imaging study. Biol Psychiatry 2009;65:550-5.

9. Nandam LS, Hester R, Wagner J, Cummins TD, Garner K, Dean AJ, *et al.* Methylphenidate but not atomoxetine or citalopram modulates inhibitory control and response time variability. Biol Psychiatry 2011;69: 902-4.

10. Nagendra HR. Defining yoga. Int J Yoga 2008;1:43-4.

11. Jerath R, Edry JW, Barnes VA, Jerath V. Physiology of long pranayamic breathing: Neural respiratory elements may provide a mechanism that explains how slow deep breathing shifts the autonomic nervous system. Med Hypotheses 2006;67:566-71.

12. Vialatte FB, Bakardjian H, Prasad R, Cichocki A. EEG paroxysmal gamma waves during Bhramari Pranayama: A yoga breathing technique. Conscious Cogn 2009;18:977-88.

13. Sidheshwar P, Niladri KM, Ravishankar N. Role of self-induced sound therapy: Bhramari Pranayama in Tinnitus. Audiol Med 2010;8: 137-41.

14. Colzato LS, Hertsig G, van den Wildenberg WP, Hommel B. Estrogen modulates inhibitory control in healthy human females: Evidence from the stop-signal paradigm. Neuroscience 2010;167:709-15.

15. Verbruggen F, Logan GD. Proactive adjustments of response strategies in the stop-signal paradigm. J Exp Psychol Hum Percept Perform 2009;35:835-54.

16. Nigbur R, Ivanova G, Sturmer B, Theta power as a marker for cognitive interference. Clin Neurophysiol 2011;122:2185-94.

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