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Perceptual and Motor Skills, 2009, 109, 1-14.

PERFORMANCE ON PSYCHOMOTOR TASKS FOLLOWING TWO YOGA-BASED RELAXATION TECHNIQUES[1, 2]

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Summary.—Previously cyclic meditation and supine rest have been shown to improve performance in a letter cancellation task requiring attention, visual scanning, and motor speed. The present study assessed the performance in 57 volunteers (all male, *M* age = 26.5 yr., *SD* = 4.6) in three tasks, viz., a digit-letter substitution task (DLST), a letter-copying task, and a circle-dotting task. The DLST assessed attention and speed of information processing, while the other 2 tests assessed motor speed. Each participant was assessed before and after three types of sessions: Cyclic Meditation, Supine Rest, and Control (no intervention). DLST scores and scores for letter-copying and circle-dotting tasks improved significantly after cyclic meditation; the same scores also improved after supine rest. There was no change after the no-intervention/Control session. From the results it was difficult to conclude whether improved DLST scores after cyclic meditation were due to better information processing speed or improved motor speed.

Meditation is recognized as a specific state of consciousness characterized by deep relaxation and increased internalized attention (Murata, Takahashi, Hamada, Omori, Kosaka, Yoshida, *et al.*, 2004). Meditators with lower scores on trait anxiety were reported to more readily experience meditation with a predominance of internalized attention, while those with higher scores on trait anxiety more readily experienced meditation with a predominance of relaxation. In another study on Zen meditation, the frontal midline theta rhythm (Fm theta), electroencephalogram, and heart rate variability were recorded simultaneously (Kubota, Sato, Toichi, Murai, Okada, Hayashi, *et al.*, 2001). The Fm theta reflects mental concentration as well as a meditative state or relief from anxiety. Both sympathetic and parasympathetic indices were increased during the appearance of Fm theta compared with control periods. Hence, meditation appears to bring about a relaxed state with heightened internalized attention and concentration.

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Meditation has also been shown to modify the attention to external stimuli and events. For example, the mismatch negativity (MMN), which is an indicator of preattentive processing, was used to study the effects of a concentrative meditation, *Sahaj Samadhi* meditation (Srinivasan & Baijal, 2007). Meditators had larger auditory MMN amplitudes than nonmeditators, suggesting that concentrative meditation enhances preattentive perceptual processes, with improved detection in auditory sensory memory.

Many studies on the effects of meditation on attention have focused on concentration meditation, which is distinct from concentrative meditation, mentioned above. In this meditation, concentration is sustained on a small object or the breath and the meditator is not diverted by distractors (Mipham, 2000). Practice of concentration meditation was shown to improve specific aspects of attention (Jha, Klein, Krompinger, & Baime, 2007). In this study, a group naïve to the meditation underwent 8 wk. of intensive training and was compared to experienced meditators taking part in a 1-mo. intensive retreat and to a meditation-naïve control group. Three functionally and neuroanatomically distinct but overlapping attentional subsystems were studied. These were: alerting, orienting, and conflict monitoring. At one assessment, the participants in the retreat showed better conflict monitoring than the other groups. At another assessment the meditators undergoing intensive training showed improved orienting relative to other groups, while participants in the retreat showed altered performance on the alerting component. This suggested that the 8-wk. intensive course improved the ability to endogenously orient attention, whereas those who took part in the retreat developed receptive attentional skills associated with an improved exogenous alerting process. Concentration meditation also decreased attentional blink (Slagter, Lutz, Greischar, Francis, Nieuwenhuis, Davis, *et al.*, 2007), while changes in the electroencephalogram and cortical thickness were found in long-term practitioners of compassion meditation (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004) and of insight meditation (Lazar, Kerr, Wasserman, Gray, Greve, Treadway, *et al.*, 2005). A functional magnetic resonance study showed that expert meditators (with an average of 19,000 hr. of practice) had more activation than novices while focusing on a simple visual stimulus, while expert meditators with over 44,000 hr. had less activation (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). Also, in response to distractor sounds, expert meditators had less activation in brain regions related to discursive thoughts and emotions, and more activation in regions related to response inhibition and attention. These findings suggested that the hours of practice influence mental processes related to attending to or ignoring specific stimuli. These findings may also explain certain changes in advanced practitioners of Transcendental Meditation,™ described below.

The effects of transcendent experiences described as occurring during the practice of Transcendental Meditation™ were studied on the contingent negative variation amplitude, rebound, and distraction effects (Travis, Tecce, Arenander, & Wallace, 2002). The contingent negative variation is an event-related potential occurring between a warning stimulus and an imperative stimulus requiring a response (Walter, Cooper, Aldridge, McCallum, & Winter, 1964). Late contingent negative variation amplitudes were largest in meditators who had transcendent experiences every day. Since late contingent negative variation reflects proactive preparatory processes including mobilization of motor, perceptual, cognitive, and attentional resources, the results suggest that transcendent experiences are related to cortical responses and executive functioning.

Another meditation technique called cyclic meditation was shown to reduce the P300 peak latency and increase the P300 peak amplitude (Sarang & Telles, 2006a). The P300 component of event-related brain potentials (ERPs) is generated when persons attend to and discriminate stimuli which differ in a single aspect. The P300 reflects fundamental cognitive events requiring attentional and immediate memory processes (Polich, 1999). The results suggested that cyclic meditation enhanced these cognitive processes. Cyclic meditation practice also improved the performance in a letter-cancellation task which requires selective attention, concentration, visual scanning abilities, and a repetitive motor response (Sarang & Telles, 2007).

The performance in a cancellation task hence requires certain mental processes related to attention, as well as motor speed, during a repetitive motor activity. Previously, a yoga program which included cyclic meditation and supine rest increased motor speed in a standard finger-tapping task (Dash & Telles, 1999). This increase in tapping speed was seen in children after a 10-day program and in adults after a 1-mo. program. Hence, it was not possible to state whether the improved performance in the cancellation task was due to improved attention or increased motor speed. For this reason, the present study was designed to assess whether cyclic meditation and supine rest would influence performance in: (i) a task which requires attention and assesses speed of information processing, as well as motor speed, and (ii) tasks for motor speed alone. The task which was used to assess attention, speed of information processing, and motor speed was a digit-letter substitution task (DLST). Two tests were used to assess motor speed. The first was a letter-copying task in which the participants had to copy a specified letter in the space provided. The number of spaces was the same as for the DLST. The other test for motor speed required participants to make dots within the circumference of two circles, as quickly as possible.

The performance in these three tasks was assessed before and after cyclic meditation, or supine rest, and this was compared to recordings before and after an equal duration of no intervention (or control period). The aim was to assess whether changes in motor speed (if any) influenced the performance on the DLST.

Method

Participants

Fifty-seven male participants ages 18 to 40 years (*M* age = 26.5 yr., *SD* = 4.6) participated in the study. All of them were in normal health based on a routine clinical examination (Swash, 2001). Also, they were all literate and could understand and undertake the tests. Participants were staying at a residential yoga center located in southern India. Their experience of the practice of cyclic meditation and relaxation while supine (supine rest) ranged between 6 and 54 mo. (*M* = 24.4, *SD* = 13.7). None of them used tobacco, intoxicants, or consumed caffeinated beverages. They were all right-hand dominant based on the Edinburgh Handedness Inventory (Oldfield, 1971). The study had been explained to them. Their participation in the study was voluntary. They were not specifically told about previous studies on cyclic meditation and supine rest. However, they may have known about them and this may have influenced the outcome of the trial, which is a limiting factor of the study. They were not told the specific hypothesis of the study or the purpose for each of the three tasks. The approval of the Institutional Ethics Committee was obtained and the participants' signed informed consent was taken.

Measures

Digit-letter substitution task.—The digit-letter substitution task consisted of a worksheet on which digits (1 to 9) were arranged randomly in 12 rows and eight columns (Natu & Agarwal, 1997). An instruction key for "letter-for-digit" substitutions was shown at the top. Participants were required to make as many letter-for-digit substitutions as possible in 90 sec. They were told that there were two possible strategies, i.e., marking all nine digits in the random order they occurred, or selecting any one digit at a time. They were to choose whichever strategy suited them. They were also told that they could follow a horizontal, vertical, or random path according to their choice. The total number of substitutions was counted and each substitution scored as 1. Where the wrong letter was substituted, these errors were counted (also as 1 each). The total numbers of substitutions and error substitutions were scored as described and the net scores were calculated by deducting errors (wrong substitutions) from the total substitutions attempted.

As this test was administered at the beginning and at the end of the interventions, which required 22.5 min., to avoid any retest effect parallel worksheets were prepared by changing the digit-letter pairs in the key and by randomly changing the sequence of digits in the working section (Agarwal, Kalra, Natu, Dadhich, & Deswal, 2002). Hence, half the participants ($n = 29$) received worksheet A before a session, while the other half ($n = 28$) received worksheet B before the session. Those who received worksheet A before the session received worksheet B after the session. This was reversed for the remaining participants. Similarly, there were different worksheets for the remaining sessions. The digit-letter substitution task has been used in a similar design in an Indian population, which indicated the validity of the task to study immediate effects (Natu & Agarwal, 1997).

Letter-copying task.—The letter-copying task measured the psychomotor and motor speed components of the digit-letter substitution task as has been described elsewhere (Morrens, Hulstijn, & Sabbe, 2008). Participants were given the same worksheets as for the DLST; however, in this task, participants did not have to attempt to substitute digits for letters based on the key provided. Instead, they were asked to fill in all the boxes provided with a single letter using their dominant hand. This was the first letter mentioned in the digit-letter substitution key. They were given 90 sec. to do this. This task was completed by all 57 participants. The total number of letters filled in was the score.

Circle-dotting task.—In the circle-dotting task, the targets were two circles drawn on paper, 6 cm in diameter with 24.5 cm between their centers. In this paper-and-pencil task, participants were asked to make a dot within the circumference of both circles alternately, using their dominant hand, as rapidly as possible. This task is based on a standard "circle-dotting task" for motor speed (Lezak, 1995). They were given 90 sec. to complete the task. Only those dots which were actually within the circumference of either circle were counted. Those which were on the circumference were not counted. Separate scores (where one correctly placed dot was scored as 1) were noted for the circle on the left and the circle on the right.

For all tasks, the task sheets were scored by a person who was unaware whether the participant was in a Cyclic Meditation or Supine Rest session and whether the assessment was made at the beginning or at the end of a session.

Procedure

The fifty-seven participants were assessed in three types of sessions, namely, (i) Cyclic Meditation, (ii) Supine Rest, and (iii) Control. The participants were first assessed in Cyclic Meditation and Supine Rest sessions. There were two schedules, (a) Cyclic Meditation on Day 1, and Supine Rest on the next day (the CM/SR schedule), and (b) Supine Rest on Day 1 and Cyclic Meditation the next day (the SR/CM schedule). Participants were randomly allocated to either schedule, to balance effects of order of sessions. In addition, all participants were assessed before and after a no-intervention Control session. Each session was 22:30 min. in duration. Assessments were made immediately at the beginning and end of each session. Separate sessions were conducted for each of the assessments. Twenty-nine out of 57 participants were assigned to Schedule 1 (CM/SR) and the remaining 28 participants were assigned to Schedule 2 (SR/CM). Since there were three assessments, each participant was assessed in three Cyclic Meditation sessions, in three Supine Rest sessions, and in three Control sessions. There were no differences in results based on the order of the sessions, when the "after" values were compared ($p > .05$, t test for unpaired data).

Meditation Sessions

Cyclic meditation.—During the Cyclic Meditation sessions, participants kept their eyes closed and followed prerecorded instructions. The instructions emphasized carrying out the practice slowly, with awareness and relaxation. The practice began by repeating a verse (0:40 min.) from the yoga text, the *Mandukya Upanishad* (Chinmayananda, 1984); followed by isometric contraction of the muscles of the body ending with supine rest (1:00 min.); slowly coming up from the supine position and standing at ease (called *tadasana*) and "balancing" the weight on both feet, called centering (2:00 min.); then the first actual posture, bending to the right (*ardhakaticakrasana,* 1:20 min.); 1:10 min. in *tadasana* for instructions about relaxation and awareness; bending to the left (*ardhakaticakrasana,* 1:20 min.); 1:10 min. in *tadasana* as before; forward bending (*padahastasana,* 1:20 min.); another 1:10 min. in *tadasana*; backward bending (*ardhacakrasana*, 1:20 min.); and slowly coming down in the supine posture with instructions to relax different parts of the body in sequence (10:00 min.). The postures were practiced slowly, with awareness of all the sensations felt. The total duration of the practice was 22:30 min. (Telles, Reddy, & Nagendra, 2000).

Supine rest.—Supine rest was practiced as traditional *shavasana* (the corpse posture), which meant lying flat on the ground with the legs apart, arms away from the sides of the body, with the palms facing upwards, while the eyes were closed (Muktibodhananda, 2004). This practice lasted 22:30 min., so that the duration was the same as for Cyclic Meditation sessions.

Control.—During this session, the participants were seated and their thoughts wandered at random. They were not given any other specific in-

AUTHOR: Is this correct?

structions, except for the fact that they were told that they were to avoid meditating. This practice lasted for 22:30 min. The session was also at the same time of the day as the Cyclic Meditation and Supine Rest sessions.

Data Analysis

Statistical analysis was done using SPSS (Version 10.0). Data of the total substitutions, errors and net scores of DLST, total scores on the letter-copying task, and total scores on the circle-dotting task were analyzed using the repeated-measures analyses of variance (ANOVAs). There were two within-subjects factors, i.e., Time (pre-, postsession) and Session (Cyclic Meditation, Supine Rest, Control). *Post hoc* tests with Bonferroni adjustment were used to detect significant differences between mean values.

The percentage changes for each of the three tasks (i.e., digit-letter substitution task, letter-copying task, and circle-dotting task) were calculated separately for Cyclic Meditation, Supine Rest, and Control sessions. The percentage change was calculated as [(after scores/before scores × 100) – 100]. Pearson correlation coefficient test was used to assess whether these percentage changes had any correlation with the length of experience practicing yoga (expressed in months).

Results

The group means and standard deviations for scores obtained in the digit-letter substitution task, letter-copying task, and circle-dotting task taken before and after Cyclic Meditation, Supine Rest, and Control sessions are shown in Table 1.

Digit-letter Substitution Task

The repeated-measures analyses of variance (ANOVAs) showed a significant difference between the three types of session for total scores ($F_{1.453,81.384} = 8.95$, $p < .001$, Huynh-Feldt epsilon = 0.73; $\eta^2 = 0.33$), errors or wrong substitutions ($F_{1.534,85.905} = 0.70$, $p < .004$, Huynh-Feldt epsilon = 0.77; $\eta^2 = 0.07$), and net scores ($F_{1.391,77.895} = 10.26$, $p < .001$, Huynh-Feldt epsilon = 0.70; $\eta^2 = 0.36$). There was a significant effect of Time for total scores ($F_{1,56} = 119.32$, $p < .001$, Huynh-Feldt epsilon = 1.00; $\eta^2 = 0.10$) and net scores ($F_{1,56} = 115.83$, $p < .001$, Huynh-Feldt epsilon = 1.00; $\eta^2 = 0.11$). There was a significant interaction between Sessions and Time for total scores ($F_{1.822,102.042} = 66.67$, $p < .001$, Huynh-Feldt epsilon = 0.88; $\eta^2 = 0.41$) and net scores ($F_{1.828,102.356} = 73.84$, $p < .001$, Huynh-Feldt epsilon = 0.91; $\eta^2 = 0.43$), suggesting the two factors were not independent.

Post hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective before states. After Cyclic Meditation sessions there was a significant increase in total scores ($p < .001$) and net scores ($p < .001$), compared to pre-session. Also, the scores after Cyclic Meditation sessions were significant-

TABLE 1

Scores Obtained in Digit-letter Substitution Task, a Letter-copying Task, and Circle-dotting Task Before and After Cyclic Meditation, Supine Rest, and Control Sessions ($N = 57$)

Task	Variables and state	Session					
		Cyclic Meditation		Supine Rest		Control	
		M	*SD*	*M*	*SD*	*M*	*SD*
Digit-letter Substitution	Total Substitutions						
	Pre	51.79	9.21	51.68	11.16	51.86	9.42
	Post	62.60*†	9.88	53.33	10.34	53.26	8.59
	Errors						
	Pre	0.18	0.43	0.35	0.74	0.30	0.57
	Post	0.11†	0.36	0.53	1.14	0.53	0.89
	Net Substitutions						
	Pre	51.61	9.19	51.33	10.88	51.56	9.36
	Post	62.49*†	9.85	52.81	9.95	52.74	8.62
Letter-copying	Total Attempted						
	Pre	86.93	13.41	86.42	12.67	85.32	10.95
	Post	98.44*†	13.24	90.16*	10.94	86.82	9.36
Circle-dotting	Left Circle						
	Pre	71.75	12.85	69.86	13.87	70.98	11.57
	Post	86.07*†	11.70	72.68*	12.90	72.33	9.62
	Right Circle						
	Pre	72.53	12.73	69.23	13.92	71.65	11.80
	Post	86.61*†	11.94	72.12*	13.00	72.44	9.48

*$p < .001$, RM ANOVA, with Bonferroni adjustment, before compared with after respective session. †$p < .001$, RM ANOVA, with Bonferroni adjustment, scores after Cyclic Meditation compared with Supine Rest and Control sessions.

ly different from scores after both Supine Rest and Control sessions for total scores ($p < .001$), errors or wrong substitutions (Cyclic Meditation vs Supine Rest, $p < .021$; Cyclic Meditation vs Control, $p < .002$; Supine Rest vs Control, $p < .001$) and net scores ($p < .001$).

Letter-copying Task

The repeated-measures ANOVAs showed a significant effect of Session for total scores ($F_{1.185,66358} = 15.05$, $p < .001$, Huynh-Feldt epsilon $= 0.58$; $\eta^2 = 0.21$). There was a significant effect of Time for total scores ($F_{1,56} = 127.19$, $p < .001$, Huynh-Feldt epsilon $= 1.00$; $\eta^2 = 0.69$). There was a significant interaction between Sessions and Time for total scores ($F_{1.217,68.158} = 88.54$, $p < .001$, Huynh-Feldt epsilon $= 0.60$; $\eta^2 = 0.61$), suggesting the two factors were not independent.

Post hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective before states. There were significant increases in total scores of the letter-copying task following Cyclic Meditation sessions ($p < .001$), Supine Rest sessions ($p < .001$), and Control sessions ($p < .002$) compared to the respective pre-session values. Also, after Cyclic Meditation sessions, the scores were significantly different from the scores after both Supine Rest and Control sessions ($p < .001$ for both comparisons).

Circle-dotting Task

The circle-dotting task showed a significant effect of Session for both left-circle scores ($F_{1.526,85.437} = 23.42$, $p < .001$, Huynh-Feldt epsilon = 0.75; $\eta^2 = 0.30$) and right-circle scores ($F_{1.565,87.66} = 28.06$, $p < .001$, Huynh-Feldt epsilon = 0.78; $\eta^2 = 0.33$). Similarly, there was a significant effect of Time for left-circle scores ($F_{1,56} = 106.69$, $p < .001$, Huynh-Feldt epsilon = 1.00; $\eta^2 = 0.66$) and right-circle scores ($F_{1,56} = 104.15$, $p < .001$, Huynh-Feldt epsilon = 1.00; $\eta^2 = 0.65$). Also, there was a significant interaction between Sessions and Time for left-circle scores ($F_{1.808,101.248} = 66.63$, $p < .001$, Huynh-Feldt epsilon = 0.88; $\eta^2 = 0.54$) and right-circle scores ($F_{1.838,102.911} = 77.21$, $p < .001$, Huynh-Feldt epsilon = 0.92; $\eta^2 = 0.58$), suggesting the two factors were not independent.

Post hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective before states. After Cyclic Meditation and Supine Rest sessions, there were significant increases in left-circle scores ($p < .001$) and right-circle scores ($p < .001$). Also, scores after Cyclic Meditation sessions were significantly different from scores after both Supine Rest and Control sessions for left-circle scores ($p < .001$) and right-circle scores ($p < .001$).

Pearson Correlations Among Scores

Pearson correlation coefficients were calculated between the percentage changes in scores on the three tasks and months of yoga practice. There was a significant positive correlation between the percentage change in net scores on the digit-letter substitution task after Cyclic Meditation with months of yoga practice ($r = .30$, $p < .05$, $N = 57$).

Discussion

Participants showed better performance in a digit-letter substitution task, as well as in tasks for motor speed, following a session of cyclic meditation. Following a period of supine rest for an equal duration there was improved performance in tasks for motor speed, but not in the digit-letter substitution task. There were no significant changes in the control group, suggesting no retest effect.

The digit-letter substitution task measures psychomotor performance (Gerrard, Wheeldon, & McDevitt, 1995). This task is based on earlier developed substitution tests (e.g., the Digit Symbol Substitution Test) but uses overlearned signs (i.e., letters) instead of the symbols used in other substitution tasks (van der Elst, van Boxtel, van Breukelen, & Jolles, 2006). The task assesses attention, speed of perception and processing, as well as a repetitive motor response requiring motor speed (Orlowiejska-Gillert, Pajak, Szczudlik, Kawalec, & Pomykalska, 1998; de Groot, Hornstra, Roozendaal, & Jolles, 2003). The results suggest that the Cyclic Meditation sessions enhanced overall performance, i.e., the total scores, but also resulted in lower numbers of wrong attempts or errors (based on net scores) compared to the Supine Rest sessions. However, before Cyclic Meditation sessions, the mean score on wrong attempts was lower than before Supine Rest or the Control sessions, though neither difference was statistically significant.

The improved scores in the letter-copying task and the circle-dotting task following Cyclic Meditation sessions show that speed for repetitive motor activity was also better after Cyclic Meditation. This may have contributed to the better performance in the DLST after Cyclic Meditation sessions, especially since the magnitude of change in the three tasks was comparable. The percentage change in the mean score on the DLST after Cyclic Meditation sessions was 21.0, while in the letter-copying and circle-dotting tasks percentage changes were 14.0 and 19.0, respectively.

Cyclic meditation is so named because it consists of alternating cycles of yoga postures interspersed with periods of supine relaxation (Nagendra & Nagarathna, 1997). This "moving meditation" was devised by Nagendra based on a description from ancient yoga texts (Chinmayananda, 1984). The practice has been shown to be followed by a period of reduced physiological arousal based on a decrease in oxygen consumption and minute ventilation (Telles, *et al*., 2000; Sarang & Telles, 2006c), changes in the heart rate variability (Sarang & Telles, 2006b), and increased slow wave sleep during the night following daytime practice of cyclic meditation (Patra & Telles, 2009). However, these changes occurred simultaneously with a decreased latency and increased amplitude in the P300 (Sarang & Telles, 2006a) as well as improved performance in a letter-cancellation task (Sarang & Telles, 2007). The P300 reflects the ability to sustain and shift attention while discriminating between stimuli which differ in a single aspect, e.g., frequency of tones (Polich, 1999). The P300 also indicates cognitive events requiring attentional and immediate memory processes. Similarly, letter-cancellation tasks also require sustained attention, as well as visual scanning and activation and inhibition of rapid responses along with motor speed. These results taken together suggest that cyclic meditation induces a state of reduced physiological arousal with improved performance in tasks requiring attention.

Several meditation techniques have been shown to reduce anxiety and feelings of tension (Kozasa, Santos, Rueda, Benedito-Silva, & De Ornellas, 2008). In many cases, a reduction in anxiety is associated with better performance. For, example, persons with high trait anxiety took longer to color name threatening words, compared to neutral words, when assessed on a modified Stroop color naming paradigm (Fox, 1993). Participants with high trait anxiety were also distracted by separate color words which produced no interference for those with low trait anxiety. The results suggested that high trait anxiety is associated with a general inability to maintain attentional focus, not specific for threatening stimuli. While anxiety was not measured in the present study, one may speculate that a reduction of anxiety could have contributed to better performance.

In a previous study, following both cyclic meditation and supine rest, participants performed better in a letter-cancellation task (Sarang & Telles, 2007). In the present study, on a different group of cyclic meditation practitioners, performance in a digit-letter substitution task improved after cyclic meditation but not after supine rest. This may be related to the fact that the two psychomotor tasks (i.e., the letter-cancellation task and the digit-letter substitution task) assess comparable, yet different cognitive abilities. The letter-cancellation task assesses the ability to sustain and shift attention, immediate memory, visual scanning, and motor speed for repetitive motor activity. The digit-letter substitution task also requires the ability to sustain and shift attention, immediate memory (of the digit-letter combination), and the task tests speed of information processing, as well as the ability to process information and shift the attentional focus between digits and letters. It is difficult to say whether the improved performance in the letter-cancellation task following both cyclic meditation and supine rest in an earlier study (Sarang & Telles, 2007), and the improved performance in the digit-letter substitution task after cyclic meditation alone in the present study, was due to differences in the abilities assessed by the tasks or the fact that the yoga practitioners in the two studies were different.

In the present study, after both cyclic meditation and supine rest, the performance in the tasks for motor speed in a repetitive motor task was improved. The circle-dotting task studied also evaluates spatial intelligence and manual speed (de Andrés, Sánchez, Hidalgo, & Díaz, 2004). The letter-copying task was used as a measure of motor speed, which allowed the repetitive motor activity component of the digit-letter substitution task to be assessed separately as has been described elsewhere (Morrens, *et al.*, 2008). The ability to carry out a repeated motor activity was better after cyclic meditation and supine rest, with a greater magnitude of improvement after cyclic meditation. This may be related to previous reports of better motor coordination and better performance in motor tasks after yoga practice which included relaxation (Madan, Thombre, Bharathi, Nambinarayan, Thakur, Krishnamurthy, *et al.*, 1992; Telles, Hanumanthaiah, Nagarathna, & Nagendra, 1993).

Improved repetitive motor activity and motor speed may have contributed to the better performance in the digit-letter substitution task. The improvement in the mean scores on the three tasks following Cyclic Meditation sessions ranged from 14.0 to 21.0%. In contrast, there was no improvement in mean DLST scores after Supine Rest, but the improvement in the letter-copying task was 4.3% and the improvement in the circle-dotting task was 4.1%. Hence, an improvement in motor speed may have contributed to the better performance on the DLST after Cyclic Meditation sessions. This is to some extent not supported by the improvement in P300 after Cyclic Meditation sessions, as the P300 latency is an index of stimulus processing rather than response generation and is used as a motor-free measure of cognitive function. Improved motor speed in a repetitive motor activity task following yoga has been considered to be related to better motor coordination (Telles, *et al.*, 1993) either associated with, or independent of, improved muscular efficiency following yoga (Madan, *et al.*, 1992).

Given the fact that yoga practice has effects on attention and motor speed, the present findings show that it is difficult to assess the exact contribution of improvement in either ability following yoga, if a task requires both abilities. Hence, in future research it would be best to use tasks which selectively measure a specific function.

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PERFORMANCE ON PSYCHOMOTOR TASKS FOLLOWING TWO YOGA-BASED RELAXATION TECHNIQUES[1,2]

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Summary.—Previously cyclic meditation and supine rest have been shown to improve performance in a letter cancellation task requiring attention, visual scanning, and motor speed. The present study assessed the performance in 57 volunteers (all male, *M* age = 26.5 yr., *SD* = 4.6) in three tasks, viz., a digit-letter substitution task (DLST), a letter-copying task, and a circle-dotting task. The DLST assessed attention and speed of information processing, while the other 2 tests assessed motor speed. Each participant was assessed before and after three types of sessions: cyclic meditation, supine rest, and no-intervention/control. DLST scores and scores for letter-copying and circle-dotting tasks improved significantly after cyclic meditation; the same scores also improved after supine rest. There was no change after the no-intervention/control session. From the results it was difficult to conclude whether improved DLST scores after cyclic meditation were due to better information processing speed or improved motor speed.

Meditation is recognized as a specific state of consciousness characterized by deep relaxation and increased internalized attention (Murata, Takahashi, Hamada, Omori, Kosaka, Yoshida, *et al.*, 2004). Meditators with lower scores on trait anxiety were reported to more

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readily experience meditation with a predominance of internalized attention, while those with higher scores on trait anxiety more readily experienced meditation with a predominance of relaxation. In another study on Zen meditation, the frontal midline theta rhythm (Fm theta), electro-encephalogram and heart rate variability were recorded simultaneously (Kubota, Sato, Toichi, Murai, Okada, Hayashi, *et al.*, 2001). The Fm theta reflects mental concentration as well as a meditative state or relief from anxiety. Both sympathetic and parasympathetic indices were increased during the appearance of Fm theta compared with control periods. Hence, meditation appears to bring about a relaxed state with heightened internalized attention and concentration.

Meditation has also been shown to modify the attention to external stimuli and events. For example, the mismatch negativity (MMN), which is an indicator of pre-attentive processing, was used to study the effects of a concentrative meditation, *Sahaj Samadhi* meditation (Srinivasan & Baijal, 2007). Meditators had larger auditory MMN amplitudes than non-meditators, suggesting that concentrative meditation enhances pre-attentive perceptual processes, with improved detection in auditory sensory memory.

Many studies on the effects of meditation on attention have focused on concentration meditation which is distinct from concentrative meditation, mentioned above. In this meditation, concentration is sustained on a small object or the breath and the meditator is not diverted by distractors (Mipham, 2000). Practice of concentration meditation was shown to improve specific aspects of attention (Jha, Klein, Krompinger, & Baime, 2007). In this study, a group who were naïve to the meditation underwent eight weeks intensive training were compared to experienced meditators taking part in an one-month intensive retreat, and to a meditation-naïve control group. Three functionally and neuroanatomically distinct but overlapping attentional subsystems were studied. These were: alerting, orienting, and conflict monitoring. At one assessment the participants in the retreat showed better conflict monitoring than the other groups. At another assessment the meditators undergoing intensive training showed improved orienting relative to other groups, while participants in the retreat showed altered performance on the alerting component. This suggested that the eight-week intensive course improved the ability to endogenously orient attention, whereas those who took part in the retreat developed receptive attentional skills associated with an improved exogenous alerting process. Concentration meditation also decreased attentional blink (Slagter, Lutz, Greischar, Francis, Nieuwenhuis, Davis, *et al.*, 2007), while changes in the electroencephalogram and cortical thickness were found in long term practitioners of compassion meditation (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004) and of insight meditation (Lazar, Kerr, Wasserman, Gray, Greve, Treadway, *et al.*. 2005). A functional magnetic resonance study showed that expert meditators (with an average of 19,000 hours of practice) had more activation than novices while focusing on a simple visual stimulus, while expert meditators with over 44,000 hours had less activation (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). Also, in response to distractor sounds, expert meditators had less activation in brain regions related to discursive thoughts and emotions, and more activation in regions related to response inhibition and attention. These findings suggested that the hours of practice influence mental processes related to attending to or ignoring specific stimuli. These findings may also explain certain changes in advanced practitioners of Transcendental Meditation, described below.

The effects of transcendent experiences described as occurring during the practice of Transcendental Meditation were studied on the contingent negative variation amplitude, rebound, and distraction effects (Travis, Tecce, Arenander & Wallace, 2002). The contingent negative variation is an event-related potential occurring between a warning stimulus and an imperative stimulus requiring a response (Walter, Cooper, Aldridge, McCallum, & Winter, 1964). Late contingent negative variation amplitudes were largest in meditators who had transcendent experiences every day. Since late contingent negative variation reflects proactive preparatory processes including mobilization of motor, perceptual, cognitive, and attentional resources, the results suggest that transcendent experiences are related to cortical responses and executive functioning.

Another meditation technique called Cyclic Meditation was shown to reduce the P300 peak latency and increase the P300 peak amplitude (Sarang & Telles, 2006c). The P300 component of event-related brain potentials (ERPs) is generated when persons attend to and discriminate stimuli which differ in a single aspect. The P300 reflects fundamental cognitive events requiring attentional and immediate memory processes (Polich, 1999). The results suggested that Cyclic Meditation enhanced these cognitive processes. Cyclic Meditation practice also improved the performance in a letter-cancellation task which requires selective attention, concentration, visual scanning abilities, and a repetitive motor response (Sarang & Telles, 2007).

The performance in a cancellation task hence requires certain mental processes related to attention, as well as motor speed during a repetitive motor activity. Previously, a yoga program which included Cyclic Meditation and supine rest increased motor speed in a standard finger-tapping task (Dash & Telles, 1999). This increase in tapping speed was seen in children after a 10-day program and in adults after a 1-mo. program. Hence it was not possible to state whether the improved performance in the cancellation task was due to improved attention or increased motor speed. For this reason the present study was designed to assess whether Cyclic Meditation and supine rest would influence performance in: (i) a task which requires attention and assesses speed of information processing, as well as motor speed and (ii) tasks for motor speed alone. The task which was used to assess attention, speed of information processing, and motor speed was a digit-letter substitution task (DLST). Two tests were used to assess motor speed. The first was a letter-copying task in which the participants had to copy a specified letter in the space provided. The number of spaces was the same as for the DLST. The other test for motor speed required participants to make dots within the circumference of two circles, as quickly as possible.

The performance in these three tasks was assessed before and after Cyclic Meditation, or supine rest, and this was compared to recordings before and after an equal duration of no intervention or control period. The aim was to assess whether changes in motor speed (if any) influenced the performance on the DLST.

Method

Participants

Fifty-seven male participants ages 18 to 40 years (*M* age = 26.5 yr., *SD* = 4.6) participated in the study. All of them were in normal health based on a routine clinical examination (Swash, 2001). Also, they were all literate and could understand and undertake the tests. Participants were staying at a residential yoga center located in southern India. Their experience of the practice of Cyclic Meditation and relaxation while supine (supine rest) ranged between 6 and 54 mo. (*M* = 24.4, *SD* = 13.7). None of them used tobacco, intoxicants, or consumed caffeinated beverages. They were all right-hand dominant based on the Edinburgh Handedness Inventory (Oldfield, 1971). The study had been explained to them. Their participation in the study was voluntary. They were not specifically told about previous studies on cyclic meditation and supine rest. However, they may have known about them and this may have influenced the outcome of the trial, which is a limiting factor of the study. They were not told the specific hypothesis of the study or the purpose for each of the three tasks. The approval of the Institutional Ethics Committee was obtained and the participants' signed informed consent was taken.

Measures

Digit-letter substitution task.—The digit-letter substitution task consisted of a worksheet on which digits (1 to 9) were arranged randomly in 12 rows and 8 columns (Natu & Agarwal, 1997). An instruction key for 'letter-for-digit' substitutions was shown at the top. Participants were required to make as many letter-for-digit substitutions as possible in 90 sec. They were told that there were two possible strategies, i.e., marking all nine digits in the random order they occurred, or selecting any one digit at a time. They were to choose whichever strategy suited them. They were also told that they could follow a horizontal, vertical, or random path according to their choice. The total number of substitutions was counted and each substitution scored as 1. Where the wrong letter was substituted, these errors were counted (also as 1 each). The total number of substitutions and errors substitutions were scored as described and the net scores were calculated by deducting errors (wrong substitutions) from the total substitutions attempted.

As this test was administered at the beginning and at the end of the interventions which required 22.5 min., to avoid any retest effect, parallel worksheets were prepared by changing the digit-letter pairs in the key and by randomly changing the sequence of digits in the working section (Agarwal, Kalra, Natu, Dadhich, & Deswal, 2002). Hence, half the participants (n=29) received one set of worksheets (A) before a session, while the other half (n=28) received worksheet B before the session. After the session, those who received worksheet A before the session received worksheet B after the session. This was reversed for the remaining participants. Similarly, there were different worksheets for the remaining sessions. The digit-letter substitution task has been used in a similar design in an Indian population, which indicated the validity of the task to study immediate effects (Natu & Agarwal, 1997).

Letter-copying task.—The letter-copying task measured the psychomotor and motor speed component of the digit-letter substitution task as has been described elsewhere

(Morrens, Hulstijn, & Sabbe, 2008). Participants were given the same worksheets as for the DLST; however, in this task, participants did not have to attempt to substitute digits for letters based on the key provided. Instead, they were asked to fill in all the boxes provided with a single letter using their dominant hand. This was the first letter mentioned in the digit-letter substitution key. They were given 90 sec. to do this. This task was completed by all 57 participants. The total number of letters filled in was the score.

Circle-dotting Task

In the circle-dotting task, the targets were two circles drawn on paper, 6 cm in diameter with 24.5 cm between their centers. In this paper-and-pencil task, participants were asked to make a dot within the circumference of both circles alternately, using their dominant hand, as rapidly as possible. This task is based on a standard 'circle-dotting task' for motor speed (Lezak, 1995). They were given 90 sec. to complete the task. Only those dots which were actually within the circumference of either circle were counted. Those which were on the circumference were not counted. Separate scores (where one correctly placed dot was scored as 1) were noted for the circle on the left and the circle on the right.

For all tasks, the task sheets were scored by a person who was unaware whether the participant was in a Cyclic Meditation or supine rest session and whether the assessment was made at the beginning or at the end of a session.

Procedure

The fifty-seven participants were assessed in three types of sessions, namely, (i) Cyclic Meditation, (ii) Supine Rest, and (iii) Control. The participants were first assessed in Cyclic Meditation and Supine Rest sessions. There were two schedules, (a) Cyclic Meditation on day one, and Supine Rest on the next day (the CM/SR schedule), and (b) Supine Rest on day one and Cyclic Meditation the next day (the SR/CM schedule). Participants were randomly allocated to either schedule, to balance effects of order of sessions. In addition all participants were assessed before and after a no intervention control session. Each session was 22:30 minutes in duration. Assessments were made immediately at the beginning and end of each session. Separate sessions were conducted for each of the assessments. Twenty-nine out of fifty-seven participants were assigned to schedule 1 (CM/SR) and the remaining twenty-eight participants were assigned to schedule 2 (SR/CM). Since there were three assessments each participant was assessed in three cyclic meditation sessions, in three supine rest sessions, and in three control sessions. There were no differences in results based on the order of the sessions, when the 'after' values were compared (p > .05, t test for unpaired data).

Meditation Sessions

Cyclic Meditation.—During the Cyclic Meditation sessions, participants kept their eyes closed and followed prerecorded instructions. The instructions emphasized carrying out the practice slowly, with awareness and relaxation. The practice began by repeating a verse (0:40 min) from the yoga text, the *Mandukya Upanishad* (Chinmayananda, 1984); followed by isometric contraction of the muscles of the body ending with supine rest (1:00 min.); slowly coming up from the supine position and standing at ease (called *tadasana*) and 'balancing' the weight on both feet, called centering (2:00 min.); then the first actual posture, bending to the right (*ardhakaticakrasana,* 1:20 min.); with 1:10 min. in *tadasana* for instructions about relaxation and awareness; bending to the left (*ardhakaticakrasana,* 1:20 min.); 1:10 min. as before; forward bending (*padahastasana*, 1:20 min.); another 1:10 min.; backward bending *(ardhacakrasana*, 1:20 min.); and slowly coming down in the supine posture with instructions to relax different parts of the body in sequence (10:00 min.). The postures were practiced slowly, with awareness of all the sensations felt. The total duration of the practice was 22:30 min. (Telles, Reddy, & Nagendra, 2000).

Supine rest.—Supine rest was practiced as traditional *shavasana* (the corpse posture), which meant lying flat on the ground with the legs apart, arms away from the sides of the body, with the palms facing upwards, while the eyes were closed (Muktibodhananda, 2004). This practice lasted 22:30 min., so that the duration was the same as for Cyclic Meditation sessions.

Control.—During this session, the participants were seated and their thoughts wandered at random. They were not given any other specific instructions, except for the fact that they were told that they were to avoid meditating. This practice lasted for 22:30 min., the session was also at the same time of the day as the Cyclic Meditation and SR sessions.

Data Analysis

Statistical analysis was done using SPSS (Version 10.0). Data of the total substitutions, errors and net scores of DLST, total scores on the letter-copying task and total scores on the circle-dotting task were analyzed using the repeated measures analyses of variance (ANOVAs). There were two within-subjects factors, i.e., Time (pre-, post-session) and Session (Cyclic Meditation, Supine Rest, Control). *Post hoc* tests with Bonferroni adjustment were used to detect significant differences between mean values.

The percentage change(s) for each of the three tasks (i.e., digit-letter substitution task, letter-copying task, and circle-dotting task) were calculated separately for Cyclic Meditation, Supine Rest and Control sessions. The percentage change was calculated as [(after scores/before scores X 100)-100]. Pearson correlation coefficient test was used to assess whether these percentage changes had any correlation with the length of experience practicing yoga (expressed in months).

Results

The group means and standard deviations for scores obtained in the digit-letter substitution task, letter-copying task, and circle-dotting task taken before and after Cyclic Meditation, Supine Rest and Control sessions are shown in Table 1.

Table 1

Digit-letter substitution task

The repeated-measures analyses of variance (ANOVA) showed a significant difference between the three types of session for total scores ($F_{1.453,81.384}$ = 8.95, p < .001, Huynh-Feldt epsilon = 0.73; η^2 = 0.33), errors or wrong substitutions ($F_{1.534,85.905}$ = 0.70, p < .004, Huynh-Feldt epsilon = 0.77; η^2 =0.07), and net scores ($F_{1.391,77.895}$ = 10.26, p < .001, Huynh-Feldt epsilon = 0.70; η^2 = 0.36). There was a significant effect of Time for total scores ($F_{1,56}$ = 119.32, p < .001, Huynh-Feldt epsilon = 1.00; η^2 =0.10) and net scores ($F_{1,56}$ = 115.83, p < .001, Huynh-Feldt epsilon = 1.00; η^2 =0.11). There was a significant interaction between Sessions and Time for total scores ($F_{1.822,102.042}$ = 66.67, p < .001, Huynh-Feldt epsilon = 0.88; η^2 = 0.41) and net scores ($F_{1.828,102.356}$ = 73.84, p < .001, Huynh-Feldt epsilon = 0.91; η^2 =0.43), suggesting the two factors were not independent.

Post hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective before states. After Cyclic Meditation sessions there was a significant increase in total scores (p < .001) and net scores (p < .001), compared to pre-session. Also, the scores after Cyclic Meditation sessions were significantly different from scores after both Supine Rest and Control sessions for total scores (p < .001), errors or wrong substitutions (Cyclic Meditation vs Supine Rest, p < .021; Cyclic Meditation vs Control, p<.002; Supine Rest vs Control, p < .001) and net scores (p < .001).

Letter-copying Task

The repeated-measures ANOVAs showed a significant effect of Session for total scores ($F_{1.185,66358}$ = 15.05, p < .001, Huynh-Feldt epsilon = 0.58; η^2 = 0.21). There was a significant effect of Time for total scores ($F_{1,56}$ = 127.19, p < .001, Huynh-Feldt epsilon =

1.00; η^2 = 0.69). There was a significant interaction between Sessions and Time for total scores ($F_{1.217,68.158}$ = 88.54, p < .001, Huynh-Feldt epsilon = 0.60; η^2 =0.61), suggesting the two factors were not independent.

Post hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective before states. There were significant increases in total scores of the letter-copying task following Cyclic Meditation sessions (p < .001), Supine Rest sessions (p < .001), and Control sessions (p < .002) compared to the respective pre-session values. Also, after Cyclic Meditation sessions, the scores were significantly different from the scores after both Supine Rest and Control sessions (p < .001 for both comparisons).

Circle-dotting task

The circle-dotting task showed a significant effect of Session for both left circle scores ($F_{1.526,85.437}$ = 23.42, p < .001, Huynh-Feldt epsilon = 0.75; η^2 = 0.30) and right circle scores ($F_{1.565,87.66}$ = 28.06, p < .001, Huynh-Feldt epsilon = 0.78; η^2 = 0.33). Similarly, there was a significant effect of Time for left circle scores ($F_{1,56}$ = 106.69, p < .001, Huynh-Feldt epsilon = 1.00; η^2 = 0.66), and right circle scores ($F_{1,56}$ = 104.15, p < .001, Huynh-Feldt epsilon = 1.00; η^2 = 0.65). Also, there was a significant interaction between Sessions and Time for left circle scores ($F_{1.808,101.248}$ = 66.63, p < .001, Huynh-Feldt epsilon = 0.88; η^2 = 0.54) and right circle scores ($F_{1.838,102.911}$ = 77.21, p < .001, Huynh-Feldt epsilon = 0.92; η^2 = 0.58), suggesting the two factors were not independent.

Post hoc tests for multiple comparisons were performed with Bonferroni adjustment and all comparisons were made with the respective before states. After Cyclic Meditation and Supine Rest sessions there were significant increases in left circle scores (p < .001) and right circle scores (p < .001). Also, scores after Cyclic Meditation sessions were significantly different from scores after both Supine Rest and Control sessions for left circle scores ($p < .001$) and right circle scores ($p < .001$).

Pearson Correlations Among Scores

Pearson correlation coefficients were calculated between the percentage changes in scores on the three tasks and months of yoga practice. There was a significant positive correlation between the percentage change in net scores on the digit-letter substitution task after Cyclic Meditation with months of yoga practice ($r = .30$, $p < .05$, $n = 57$).

Discussion

Participants showed better performance in a digit-letter substitution task, as well as in tasks for motor speed following a session of cyclic meditation. Following a period of supine rest for an equal duration there was improved performance in tasks for motor speed, but not in the digit-letter substitution task. There were no significant changes in the control group, suggesting no retest effect.

The digit-letter substitution task measures psychomotor performance (Gerrard, Wheeldon, & McDevitt, 1995). This task is based on earlier developed substitution tests (e.g., the Digit Symbol Substitution Test) but uses over-learned signs (i.e., letters) instead of the symbols used in other substitution tasks (van der Elst, van Boxtel, van Breukelen, & Jolles, 2006). The task assesses attention, speed of perception and processing, as well as a repetitive motor response requiring motor speed (Orlowiejska-Gillert, Pajak, Szczudlik, Kawalec, & Pomykalska, 1998; de Groot, Hornstra, Roozendaal, & Jolles, 2003). The results suggest that the Cyclic Meditation sessions enhanced overall performance, i.e., the total scores, but also resulted in lower numbers of wrong attempts or errors (based on net scores) compared to the supine rest sessions. However, before Cyclic Meditation sessions, the mean score on wrong attempts was lower than before Supine Rest or the Control sessions, though neither difference was statistically significant.

The improved scores in the letter copying-task and the circle-dotting task following Cyclic Meditation sessions show that speed for repetitive motor activity was also better after Cyclic Meditation. This may have contributed to the better performance in the DLST after Cyclic Meditation sessions, especially since the magnitude of change in the three tasks was comparable. The percent change in the mean score on the DLST after Cyclic Meditation sessions was 21.0, while in the letter-copying and circle-dotting task percent changes were 14.0 and 19.0, respectively.

Cyclic meditation is so named because it consists of alternating cycles of yoga postures interspersed with periods of supine relaxation (Nagendra & Nagarathna, 1997). This "moving meditation" was devised by Nagendra based on a description from ancient yoga texts (Chinmayananda, 1984). The practice has been shown to be followed by a period of reduced physiological arousal based on a decrease in oxygen consumption and minute ventilation (Telles, *et al*., 2000; Sarang & Telles, 2006a), changes in the heart rate variability (Sarang & Telles, 2006b) and increased slow wave sleep during the night following daytime practice of cyclic meditation (Patra & Telles, 2009). However, these changes occurred simultaneously with a decreased latency and increased amplitude in the P300 (Sarang & Telles, 2006c) as well as improved performance in a letter-cancellation task (Sarang & Telles, 2007). The P300 reflects the ability to sustain and shift attention while discriminating between stimuli which differ in a single aspect, e.g., frequency of tones (Polich, 1999). The P300 also indicates cognitive events requiring attentional and immediate memory processes. Similarly, letter-cancellation tasks also require sustained attention, as well as visual scanning and activation and inhibition of rapid responses along with motor speed. These results taken together suggest that cyclic meditation induces a state of reduced physiological arousal with improved performance in tasks requiring attention.

Several meditation techniques have been shown to reduce anxiety and feelings of tension (Kozasa, Santos, Rueda, Benedito-Silva, & De Ornellas, 2008). In many cases a reduction in anxiety is associated with better performance. For, example, persons with high trait anxiety took longer to color name threatening words, compared to neutral words, when assessed on a modified Stroop color naming paradigm (Fox, 1993). Participants with high trait anxiety were also distracted by separate color words which produced no interference for those with low trait anxiety. The results suggested that high trait anxiety is associated with a general inability to maintain attentional focus, not specific for threatening stimuli. While anxiety was not measured in the present study, one may speculate that a reduction of anxiety could have contributed to better performance.

In a previous study, following both cyclic meditation and supine rest, participants performed better in a letter-cancellation task (Sarang & Telles, 2007). In the present study, on a different group of cyclic meditation practitioners, performance in a digit-letter substitution task improved after cyclic meditation but not after supine rest. This may be related to the fact that the two psychomotor tasks (i.e., the letter-cancellation task and the digit-letter substitution task) assess comparable, yet different cognitive abilities. The letter-cancellation task assesses the ability to sustain and shift attention, immediate memory, visual scanning, and motor speed for repetitive motor activity. The digit-letter substitution task also requires the ability to sustain and shift attention, immediate memory (of the digit-letter combination), and the task tests speed of information processing, as well as the ability to process information and shift the attentional focus between digits and letters. It is difficult to say whether the improved performance in the letter-cancellation task following both cyclic meditation and supine rest in an earlier study (Sarang & Telles, 2007) and the improved performance in the digit-letter substitution task after cyclic meditation alone in the present study, was due to differences in the abilities assessed by the tasks or the fact that the yoga practitioners in the two studies were different.

In the present study, after both cyclic meditation and supine rest, the performance in the tasks for motor speed in a repetitive motor task was improved. The circle-dotting task studied also evaluates spatial intelligence and manual speed (de Andrés, Sánchez, Hidalgo, & Díaz, 2004). The letter-copying task was used as a measure of motor speed, which allowed the repetitive motor activity component of the digit-letter substitution task to be assessed separately as has been described else where (Morrens, Hulstijn, & Sabbe, 2008) . The ability to carry out a repeated motor activity was better after cyclic meditation and supine rest, with a greater magnitude of improvement after cyclic meditation. This may be related to previous reports of better motor coordination and better performance in motor tasks after yoga practice which included relaxation (Madan, Thombre, Bharathi, Nambinarayan, Thakur, Krishnamurthy, *et al.*, 1992; Telles, Hanumanthaiah, Nagarathna, & Nagendra, 1993).

Improved repetitive motor activity and motor speed may have contributed to the better performance in the digit-letter substitution task. The improvement in the mean scores on the three tasks following Cyclic Meditation sessions ranged from 14.0 to 21.0%. In contrast, there was no improvement in mean DLST scores after Supine Rest, but the improvement in the letter-copying task was 4.3% and the improvement in the circle-dotting task was 4.1%. Hence, an improvement in motor speed may have contributed to the better performance on the DLST after Cyclic Meditation sessions. This is to some extent not supported by the improvement in P300 after Cyclic Meditation sessions, as the P300 latency is an index of stimulus processing rather than response generation and is used as a motor-free measure of cognitive function. Improved motor speed in a repetitive motor activity task following yoga has been considered to be related to better motor coordination (Telles, *et al.*, 1993) either associated with, or independent of, improved muscular efficiency following yoga (Madan, *et al.*, 1992).

Given the fact that yoga practice has effects on attention, and motor speed, the present findings show that it is difficult to assess the exact contribution of improvement in either ability following yoga, if a task requires both abilities. Hence, in future research it would be best to use tasks which selectively measure a specific function.

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TABLE 1
Scores Obtained in Digit-letter Substitution Task, a Letter-copying Task, and Circle-dotting Task Before and After Cyclic Meditation, Supine Rest, and Control Sessions (*N* = 57)

Task	Variables and state	Session					
		Cyclic Meditation		Supine Rest		Control	
		M	*SD*	*M*	*SD*	*M*	*SD*
Digit-letter substitution	Total Substitutions						
	Pre	51.79	9.21	51.68	11.16	51.86	9.42
	Post	62.60†‡	9.88	53.33	10.34	53.26	8.59
	Errors						
	Pre	0.18	0.43	0.35	0.74	0.30	0.57
	Post	0.11‡	0.36	0.53	1.14	0.53	0.89
	Net Substitutions						
	Pre	51.61	9.19	51.33	10.88	51.56	9.36
	Post	62.49†‡	9.85	52.81	9.95	52.74	8.62
Letter-copying	Total attempted						

	Pre	86.93	13.41	86.42	12.67	85.32	10.95
	Post	98.44†‡	13.24	90.16†	10.94	86.82	9.36
Circle-dotting	Left circle						
	Pre	71.75	12.85	69.86	13.87	70.98	11.57
	Post	86.07†‡	11.70	72.68†	12.90	72.33	9.62
	Right circle						
	Pre	72.53	12.73	69.23	13.92	71.65	11.80
	Post	86.61†‡	11.94	72.12†	13.00	72.44	9.48

†$p < .001$, RM ANOVA, with Bonferroni adjustment, before compared with after of respective session.

‡$p < .001$, RM ANOVA, with Bonferroni adjustment, scores after Cyclic Meditation compared with Supine Rest and Control sessions.