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# Effects of Level of Meditation Experience on Attentional Focus: Is the Efficiency of Executive or Orientation Networks Improved?

DAVINA CHAN, Ph.D.[1] and MARJORIE WOOLLACOTT, Ph.D.[2]

## ABSTRACT

The present investigation examined the contributions of specific attentional networks to long-term trait effects of meditation. It was hypothesized that meditation could improve the efficiency of executive processing (inhibits prepotent/incorrect responses) or orientational processing (orients to specific objects in the attentional field). Participants (50 meditators and 10 controls) were given the Stroop (measures executive attention) and Global-Local Letters (measures orientational attention) tasks. Results showed that meditation experience was associated with reduced interference on the Stroop task ($p < 0.03$), in contrast with a lack of effect on interference in the Global-Local Letters task. This suggests that meditation produces long-term increases in the efficiency of the executive attentional network (anterior cingulate/prefrontal cortex) but no effect on the orientation network (parietal systems). The amount of time participants spent meditating each day, rather than the total number of hours of meditative practice over their lifetime, was negatively correlated with interference on the Stroop task ($r = -0.31$, $p < 0.005$).

## INTRODUCTION

Meditation, a form of mental training that has been shown to increase mental focus and reduce stress,[1–3] has become an increasingly used tool in both the medical and clinical psychology arena. It is considered a family of techniques, which have in common a conscious attempt to focus attention (e.g., by observing the breath and avoiding everyday thoughts). A large number of studies have investigated the effects of meditation on physiologic change and/or its contribution to the reduction of medical or psychologic symptoms. For example, experimental work has shown meditation to be effective in the treatment of hypertension,[4–6] insomnia,[7,8] clinical anxiety,[9–11] psoriasis,[12] and the improvement of immune function.[1]

Studies on meditation training have examined two distinct effects of meditation. The first, called a state effect, refers to the short-term consequences of meditation practice on the individual's state. This would include changes in electroencephalogram (EEG), bodily awareness, relaxation, emotions, and attention. The second, called a trait effect, refers to long-lasting changes in these same dimensions, which continue during the meditator's daily life.[13]

One hypothesized consequence of meditation practice, both at the state and trait effect levels, is an increase in the ability to focus attention. There are a number of neural networks that have been shown to be involved in different aspects of attentional function, including, among others, the executive attentional network (frontal cortex and cingulate gyrus) and the orienting attentional network (posterior parietal lobe).[14,15]

Recent studies of the state effects of meditation include EEG and neuroimaging studies, undertaken to elucidate the attentional mechanisms contributing to these short-term effects of meditation. They have demonstrated a relationship between meditation and an increase in regional cerebral

[1]Department of Psychology, University of California, Berkeley, Berkeley, California, United States.
[2]Department of Human Physiology, University of Oregon, Eugene, Oregon, United States.

blood flow in frontal and anterior cingulate regions of the brain.[1,16–18] This has been hypothesized to be associated with increased executive attentional focus, because previous studies have shown a correlation between increased frontal activity and executive attention tasks.[13] Other studies have shown a decrease in activity in the attentional orientation association area of the superior parietal lobe,[19] and increased EEG coherence, also involved in attention.[20]

Although much research has focused on attentional changes associated with the process of meditation itself, studies of attentionally related trait effects of meditation have been relatively few in number. The small number of studies in this area is rather surprising because meditation has to do with a conscious attempt to improve the regulation of attention on a long-term basis, and the study of attention has been a central topic in cognitive psychology.

The present investigation examined the contributions of specific attentional networks to long-term trait effects of meditation. It was hypothesized that (1) meditation could improve the efficiency of orientational processing, through training attention toward a specific object; or (2) it could improve the efficiency of executive processing, which monitors for conflict in sensory information and inhibits prepotent or incorrect responses.

We examined the long-term effects of meditation on attention by comparing meditators who differed in level of experience, as measured by minutes of meditation/day and by total hours of meditation in their lifetime. We also compared two types of meditation practice: concentrative meditation and opening-up meditation. Shapiro,[21] in providing an operational definition of meditation for the American Psychiatric Association, subdivided meditation into these two types. In concentrative meditation, meditators are instructed to pay attention to the meditation object and, each time they notice that awareness has shifted away from the object, to return attention to it. In contrast, opening-up meditation involves an attempt to expand awareness to feelings, thoughts, and sensations as they arise, without fostering judgment, interpretation, or elaboration of the occurrence. One might thus expect these two basic types of meditation to differentially affect performance on attentional tasks.

To minimize possible effects of motivation or personality on performance, this study focused primarily on a comparison of the attentional performance by meditators with various levels of experience. However, we also examined the long-term effects of meditation on attention by comparing meditators with different levels of experience with control subjects, who were not meditators.

## METHODS

### *Participants*

Participants in the meditation group were recruited from six meditation centers in the Berkeley area (Spirit Rock, Shambhala Center, Nyingma Institute, Transcendental Meditation Center, Jaffe Institute, and Siddhi Meditation Center). Permission to recruit meditative participants and conduct research was obtained from the director of each meditation center prior to recruitment of participants. Nonmeditating control participants were initially solicited by flyers posted at the University of California, Berkeley. Additional control subjects were recruited from the North Oakland Senior Center.

Fifty (50) meditators (22 male/28 female) and 10 nonmeditators (5 male/5 female) participated. Meditators were classified as concentrative ($n = 20$; those practicing Transcendental Meditation, Sufi meditation, and Hindu meditation, from the Transcendental Meditation Center, the Jaffe Institute, and the Siddhi Meditation Center, respectively) or opening-up ($n = 30$; those practicing vipassana or Tibetan Buddhist meditations from Spirit Rock, the Shambhala Center, and the Nyingma Institute).

Level of meditative experience and type of meditation practiced were assessed by a questionnaire completed at the beginning of the experiment. Level of experience was assessed by minutes of meditation/day and by total number of hours of practice through life. The type of meditation practiced was categorized either as concentrative or opening-up based on participants' descriptions of their current practice.

Nonmeditators ranged in age from 25 to 64, with a mean age of 43.3 (SD: 15.8); meditators ranged in age from 18 to 68, with a mean age of 41.9 (SD: 12.3) years. Meditators ranged in experience from 6 to 150 minutes/day, and from 82 to 19,200 hours overall. Participants were classified as belonging to one of four educational levels, depending on the highest degree obtained—Level 1: High School diploma; Level 2: Bachelor's degree; Level 3: Master's degree; or Level 4: beyond Master's degree. Overall mean educational level was 2.4. There were no significant differences between meditators and nonmeditators in age, education, or gender ($p > 0.20$), nor any differences between concentrative and opening-up meditators on these dimensions ($p > 0.16$). No significant correlation was found between minutes of meditation/day and age, education, or gender for the 50 meditators.

### *Stroop Task*

Participants were administered a standardized three-page paper Stroop test (Golden Stroop Color and Word Test).[22] A paper Stroop test, rather than a computerized version, was used to allow for a more accurate assessment of possible carryover interference effects from one trial to the next because participants would not have to wait for the computer to generate a new stimulus after completion of each trial. The first page (Word) of the test consisted of names of colors (red, green, blue), printed in black ink, and participants were given 45 seconds to read the columns of words as fast as they could. The second page (Color) consisted of XXXX's printed in red, green, or blue ink, and participants were told to name the color in which the XXXX's were printed as quickly as possible. The third page (Color-Word) consisted of color names from the first page printed in the colors of the second page, and participants named the color in which the words were printed. There were 100 items/page, arranged in 5 columns with 20 words/column. The items were arranged in a quasirandom fashion with the constraint that the same item did not appear consecutively. Participants were told that if they finished reading all items before time was called, they should start again from the top. They were also told to correct any errors they made.

### Global-local letters task

The stimuli for the Global-Local Letters task were generated on a 15-inch monitor in white on a dark background. A set of hierarchically formed stimuli was used in this experiment. Large letters were constructed from the appropriate placement of small letters in a $4 \times 5$ matrix. Small letters subtended 0.64° visual angle vertically and 0.42° horizontally. Large letters subtended 3.6° visual angle vertically and 2.3° horizontally.

The letters "H," and "S" served as targets. On congruent trials, the same letter appeared at the local and global levels (i.e., both local and global letters were "H", or both were "S"). On incongruent trials, the local and global letters were different (i.e., global "H" and local "S," or global "S" and local "H"). On neutral trials, the stimulus was either one small letter presented alone (local condition); or a large letter composed of small "O"s (global condition). Each trial was preceded by the appearance of a fixation point in the center of the monitor, subtending 0.21° visual angle.

Participants sat in front of a computer monitor (viewing distance 54 cm). A tone (500 ms) signaled the beginning of each trial and was followed after 100 ms by a central fixation point (500 ms). Participants were instructed to look directly at the fixation point and not to move their eyes. The fixation point was followed by the stimulus (100 ms), appearing randomly and equally often in the left or right portion of the screen. Lateralized stimuli were used because prior studies have found that this maximizes interference effects.[23,24] Stimuli appeared 2.7° of visual angle out from the fixation point. A 1000 ms intertrial interval followed a response.

Stimuli were presented in two blocks of 100 trials. Each block consisted of 40 congruent trials, 40 incongruent trials, and 20 neutral trials, and was preceded by 9 practice trials (not included in the analyses). In one block (the local condition), the small letters served as the targets and in the other (the global condition), the large letter served as the target. Participants pressed the left mouse button (left index finger) for an "H" target, and the right mouse button (right index finger) for an "S" target. Order of presentation of the two blocks was counterbalanced between subjects.

## RESULTS

### Stroop task

Analyses showed that meditation experience, as measured by minutes of meditation/day, was negatively correlated with Stroop interference ($r = -0.31$, $p < 0.005$, one-tailed, $df = 58$; Fig. 1). This was primarily attributable to a significant positive correlation between minutes of meditation/day and number of items named on the Color-Word page ($r = 0.40$, $p < 0.001$, $df = 58$). Overall, these results suggest that the more time persons spend meditating each day, the less susceptible they are to Stroop interference.

No correlation was found between meditation experience as measured by total number of hours of meditative practice and Stroop interference ($r = -0.17$), nor was there any difference in interference scores between concentrative and opening-up meditators ($p > 0.70$). Correlational data for the Stroop experiment are summarized in Table 1. Note in Table 1 and Figure 1 that the Stroop effects for the opening-up meditators and for all meditators combined were both significant, but that for the concentrative meditators alone it was not.

*T* tests were performed to compare the performance of meditators versus nonmeditators overall. Mean Word, Color, and Color-Word scores, as well as Stroop interference scores, for the two types of meditators and nonmeditating controls are presented in Table 2. Meditators showed superior overall performance on the Stroop task, as indicated by significantly higher scores than nonmeditators on the Word page ($p < 0.001$, one-tailed, $df = 58$), the Color page ($p < 0.002$, $df = 58$), and the Color-Word page ($p < 0.0001$, $df = 58$). Moreover, they demonstrated significantly less Stroop interference than controls did ($p < 0.03$, $df = 58$). No dif-

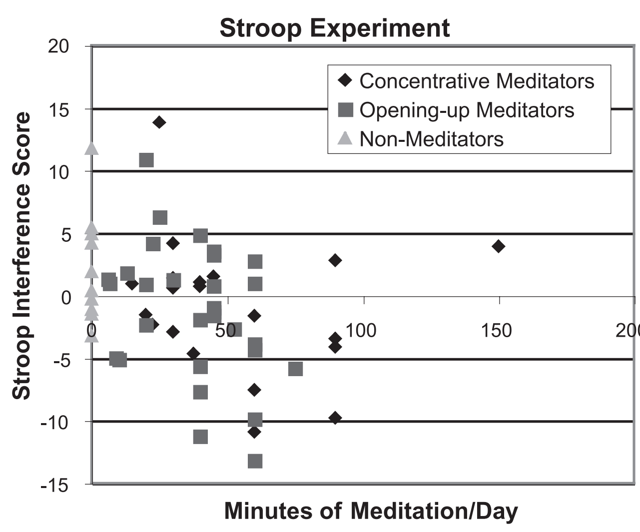


**FIG. 1.** Stroop interference scores of meditators plotted against minutes of meditation/day, showing negative correlations with Stroop interference ($r = -0.31$, $p < 0.005$).

TABLE 1. CORRELATIONS BETWEEN STROOP SCORES AND MEDITATIVE EXPERIENCE FOR EACH OF THE THREE SUBJECT GROUPS

| | | *Stroop score* | *Color-Word score* | *Word score* | *Color score* |
|---|---|---|---|---|---|
| All | Min of medit/dy | **−0.308** | **0.399** | **0.285** | 0.212 |
| | Total hrs of medit | −0.216 | 0.212 | 0.148 | 0.143 |
| Concentrative | Min of medit/dy | −0.182 | 0.276 | 0.092 | 0.167 |
| | Total hrs of medit | −0.140 | 0.312 | 0.077 | 0.360 |
| Opening-up | Min of medit/dy | **−0.353** | 0.225 | 0.065 | −0.105 |
| | Total hrs of medit | −0.262 | 0.089 | −0.030 | −0.209 |

Medit, meditation; dy, day.

ference was found between concentrative and opening-up meditators in number of items named on any of the three pages, nor was there any difference in Stroop interference between the two types of meditators ($p > 0.5$).

Participants' overall error rate was very low, averaging 0.71%. As might be expected, mean error rates were higher for the Color-Word page than for the Word or Color page, though this difference reached significance only in the case of the Word page ($p < 0.02$). There was no indication of a speed–accuracy tradeoff. There was no statistically significant effect of gender on Stroop interference, or on Color, Word, or Color-Word scores.

### *Global-Local Letters Task*

Interference was assessed using a congruency effect score, calculated as reaction times (RTs) on incongruent trials minus RTs on congruent trials. No correlation was found between the congruency effect score and meditation experience, as measured by minutes of meditation/day or total number of hours of practice, in either the global or the local condition ($p$s $> 0.13$). However, meditation experience, as measured by meditation minutes/day, was associated with faster response time across all trial types in both global and local conditions. This effect of meditation experience on RTs reached significance for congruent trials ($r = -0.31$, $p < 0.01$, $df = 58$), incongruent trials ($r = -0.22$, $p < 0.05$, $df = 58$), and neutral trials ($r = -0.28$, $p < 0.02$, $df = 58$) in the global condition; and for neutral trials ($r = 0.27$, $p < 0.02$, $df = 58$) in the local condition. This suggests that meditation experience enhances one's general performance on attentional tasks.

TABLE 2. ITEMS READ FOR EACH STROOP TASK PAGE AND STROOP SCORE FOR THE THREE SUBJECT GROUPS

| | *Concentrative* | *Opening-up* | *Nonmeditator* |
|---|---|---|---|
| Word score | 117.0 (13.1) | 114.5 (16.1) | 98.4 (15.9) |
| Color score | 77.5 (7.5) | 78.9 (10.8) | 67.4 (12.1) |
| Color-Word score | 47.4 (6.1) | 47.8 (7.7) | 37.7 (8.1) |
| Stroop score | −0.9 (5.4) | −1.3 (5.3) | 2.2 (4.4) |

No significant difference was found between concentrative and opening-up meditators on interference scores or response time on any of the trial types ($p$s $> 0.25$). Correlational data for the Global-Local Letters Task are summarized in Table 3.

RTs for each of the types of trials in the global and local conditions are presented in Table 4 for the two types of meditators and nonmeditating controls. *T* test comparisons revealed that, in the global condition, meditators were faster in responding on all three trial types than nonmeditators ($p < 0.04$, $df = 58$ for congruent trials; $p < 0.07$, $df = 58$ for incongruent trials; $p < 0.08$, $df = 58$ for neutral trials); in the local condition, meditators were faster in responding on both congruent and neutral trials than nonmeditating controls, but the difference reached significance only for neutral trials ($p < 0.05$, $df = 58$).

As expected, participants were significantly faster on congruent than incongruent trials ($p < 0.0001$, one-tailed, in both global and local conditions) and significantly faster on neutral than incongruent trials ($p < 0.0001$ in both local and global conditions). Moreover, as in prior global-local letter identification studies,[25] RTs were overall significantly faster in the global than the local condition ($p < 0.0001$ for neutral, congruent, and incongruent trials). In addition, interference, as assessed by the congruency effect score, was greater in the local than the global condition ($p < 0.04$).

Participants' error rates were very low, averaging 0.11% in the global condition and 0.15% in the local condition. Error rates on incongruent trials were higher than on congruent trials ($p < 0.01$, two-tailed, for the global condition; $p < 0.001$ for the local condition) or on neutral trials ($p < 0.06$ for the global condition; $p < 0.006$ for the local condition), indicating no speed–accuracy tradeoff. There was no significant effect of gender either in the congruency effect or in any condition.

## DISCUSSION

This research examined the contributions of specific attentional networks to long-term trait effects associated with meditation practice. It was hypothesized that (1) meditation

TABLE 3. CORRELATIONS BETWEEN GLOBAL-LOCAL LETTERS TASK SCORES AND MEDITATIVE EXPERIENCE FOR EACH OF THE THREE SUBJECT GROUPS

| | | *Global condition* | | | |
|---|---|---|---|---|---|
| | | *I-C* | *Congruent* | *Incongruent* | *Neutral* |
| All | Min of medit/dy | 0.171 | **−0.310** | **−0.222** | **−0.279** |
| | Total hrs of medit | 0.174 | −0.112 | −0.035 | −0.115 |
| Concentrative | Min of medit/dy | 0.364 | **−0.465** | −0.269 | **−0.454** |
| | Total hrs of medit | 0.231 | −0.076 | 0.034 | −0.091 |
| Opening-up | Min of medit/dy | 0.034 | −0.163 | −0.142 | −0.161 |
| | Total hrs of medit | 0.286 | −0.247 | −0.152 | −0.267 |
| | | *Local condition* | | | |
| | | *I-C* | *Congruent* | *Incongruent* | *Neutral* |
| All | Min of medit/dy | 0.018 | −0.116 | −0.088 | **−0.273** |
| | Total hrs of medit | 0.054 | −0.047 | −0.013 | −0.112 |
| Concentrative | Min of medit/dy | −0.198 | **−0.404** | **−0.415** | **−0.555** |
| | Total hrs of medit | −0.067 | 0.093 | 0.024 | −0.066 |
| Opening-up | Min of medit/dy | 0.102 | −0.105 | −0.058 | −0.109 |
| | Total hrs of medit | 0.112 | −0.243 | −0.179 | −0.166 |

*Note:* Bold denotes statistically significant.
Medit, meditation; dy, day.

could either improve the efficiency of executive processing (which monitors for conflict in sensory information and inhibits prepotent or incorrect responses, related to attention to objects outside the intended field of focus); or (2) it could improve the efficiency of orientational processing (through training to orient the attention toward a specific object as part of attentional focus). It was also hypothesized that these effects would be greater for individuals with increased duration of meditation practice.

TABLE 4. MEAN REACTION TIMES FOR EACH OF THE GLOBAL-LOCAL LETTERS TASK TRIALS FOR THE THREE SUBJECT GROUPS

| | *Global condition* | | |
|---|---|---|---|
| | *Concentrative* | *Opening-up* | *Nonmeditator* |
| Neutral | 5172 (664) | 5000 (827) | 5460 (847) |
| Congruent | 5077 (679) | 4954 (890) | 5504 (850) |
| Incongruent | 5300 (684) | 5209 (965) | 5709 (1075) |
| I-C | 224 (325) | 255 (226) | 205 (569) |
| | *Local condition* | | |
| | *Concentrative* | *Opening-up* | *Nonmeditator* |
| Neutral | 5842 (637) | 5643 (1085) | 6270 (1067) |
| Congruent | 6089 (609) | 5833 (1283) | 5975 (701) |
| Incongruent | 6589 (850) | 6195 (1419) | 6301 (1102) |
| I-C | 500 (536) | 362 (516) | 326 (891) |

Results showed that a significant reduction in interference in the Stroop task was associated with meditation experience. This is in contrast with a lack of effect of meditation on Global-Local Letters task interference. This suggests that meditation produces long-term increases in the efficiency of the executive attentional network (anterior cingulate/prefrontal cortex) but no effect on the orientation network (parietal systems). Thus, it appears to improve networks involved in inhibiting automatic responses (for example, inhibiting the shift of attention to distracting externally generated stimuli or internally generated thoughts) in favor of the desired response (remaining focused on the desired object or task). Meditators were also faster on all tasks. This could be due to enhanced visual–motor abilities or to a greater ability to focus attention in general.

Meditation experience was similarly associated with faster response times across all trial types on the Global-Local Letters identification task. Though no correlation was specifically found between meditation and direct measures of interference (i.e., congruency effect scores) in this experiment, meditation experience, as measured by minutes of meditation/day, was associated with a facilitation in overall performance on this attentional task. Participants who spent more time meditating each day responded more rapidly on average across all trial types. Furthermore, as a group, meditators responded faster than nonmeditators across all trial types, except in the incongruent trials in the local condition where mean reaction times of meditators and nonmeditators were essentially identical. However, as in the case of the Stroop experiment, it is possible that this overall facilitation in task performance in meditators is due to enhanced visual-motor abilities rather than greater attentional abilities in general.

Perhaps the most surprising finding of the present study was that it is primarily the amount of time participants spent meditating each day, rather than total number of hours of meditative practice overall, that affected performance on the attentional tasks in this study. In both experiments, it was minutes of meditation/day, rather than hours of practice, that correlated significantly with performance scores.

No overall difference was found between concentrative and opening-up meditators in performance scores on either of the experiments. The fact that no significant difference was found is probably due to the fact that the two types of meditation—concentrative and opening-up—are actually fundamentally similar. Opening-up meditation, as well as concentrative meditation, trains the mind to focus attention on one object, though this object changes over time in the case of opening-up meditation. Moreover, practice of most opening-up meditations is generally preceded by an extensive period of concentrative meditation. Conversely, extensive practice of concentrative meditation generally leads naturally into a type of opening-up meditation.

One limitation of the study is that all subjects performed at nearly perfect levels on the Global-Local Letters task. It is possible that a more difficult task would be better at detecting orienting effects. A second limitation of the study is that differences between meditators and nonmeditators on task performance could also be caused by differences in the type of individual who is attracted to meditation or in motivation. For example, if meditators believed that the goal of the study was to validate meditation, they might be extremely motivated to do well, and thus perform the test more quickly than if they were performing the test for other reasons. An attempt was made in the study to minimize this potential problem by focusing primarily on correlations between level of meditative experience and task performance. Furthermore, analyses did not show any significant difference between meditators and control subjects in educational level. However, the only way to address this issue fully would be to conduct a properly controlled longitudinal study, examining Stroop interference changes occurring as a result of a specific period of meditation training as compared to a control group, given equal periods of training in a nonmeditative task.

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Address reprint requests to:
*Marjorie Woollacott, Ph.D.*
*Department of Human Physiology*
*1240 University of Oregon*
*1525 University Street, Room 122C*
*Eugene, OR 97403-1240*

*E-mail:* mwool@uoregon.edu