

Attention training and attention state training

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The ability to attend and to exercise cognitive control are vital aspects of human adaptability. Several studies indicate that attention training using computer based exercises can lead to improved attention in children and adults. Randomized control studies of exposure to nature, mindfulness and integrative body-mind training (IBMT) yield improved attention and self-regulation. Here, we ask how attention training and attention state training might be similar and different in their training methods, neural mechanisms and behavioral outcomes. Together these various methods lead to practical ways of improving attention and self-regulation.

Improving attention

A very diverse set of training methods have been shown to improve aspects of attention and self-regulation. These methods could be classified into two different groups, based on their origin: methods arising from Asian traditions (e.g. integrative body-mind training [IBMT] and mindfulness) and methods developed in Europe and the USA (practice). Probably because these two groups of methods originate in separate traditions, there has been no published discussion of the similarities and differences between them and the mechanisms underlying them. More detailed understanding of these methods might allow for better choices in program design and lead to their integration in practical applications for children, adults and elderly populations who wish to improve these skills.

Here, we have chosen to discuss these two groups of methods under the headings attention training (AT) and attention state training (AST). This is partly because the goal of the western approach has been to alter specific networks related to cognitive tasks, whereas the eastern approach has been to achieve a state leading to more efficient self-regulation. Different ways of categorizing these methods would, of course, be possible, but by comparing them along these lines, we hope to provide an informative overview of the results obtained with these methods and to provide a principled basis for testing the similarity and differences between their mechanisms and outcomes.

A closer look at AT and AST

Several studies featuring random assignment to experimental and control groups involve training of attention and memory and show improvement in both specific skills

closely related to the training and to more general cognitive abilities [1–4]. All of these methods involve practice in some cognitive skill by repetitive trials on tasks similar to those used in schools or cognitive psychology laboratories. All of these studies aim for long term improvement in attention, but in most cases only short term improvements close to the training have been well studied.

On the surface, these AT methods differ considerably from mindfulness training, exposure to nature settings or IBMT, which we group as AST. Recently, both IBMT (emphasizing body-mind balance) and nature exposure (using attention restoration theory) have used randomized designs with attention measures similar to those used with AT and have also shown significantly greater improvements in attention following training than those from control groups (Figure 1). Similar to studies of AT, these studies aim at long-term improvements. An attentional assay used for both types of study is the attention network test (ANT), which we present in more detail in Box 1.

AT

AT means practice in conflict-related tasks, working memory tasks or other tasks involving executive control mechanisms. These tasks often use repetitive trials that involve executive control or, in some cases, use curricula designed with the goal of exercising control mechanisms. Mental exercise in this form of training requires directed attention and effortful control to train specific brain networks [7–10].

Child AT studies

Several studies of AT have involved children, on the assumption that this might influence later school performance. For example, one experiment [4] examined the efficiency of attentional networks in 4- and 6-year-old children before and after 5 days of computer exercises. The exercises included learning to use a joystick, prediction, working memory and the resolution of conflict. They were designed to require executive attention and were compared with interactive video experience for control groups. Greater improvement in the executive attention network and in IQ was found in the experimental group in comparison to the control group. There were no differences between the groups, however, on a questionnaire [11] that dealt with various temperamental characteristics such as negative and positive affect.

Another study with young children has been carried out in classrooms using a curriculum designed to exercise executive control individually and in groups. Improvements in tasks involving conflict resolution were obtained

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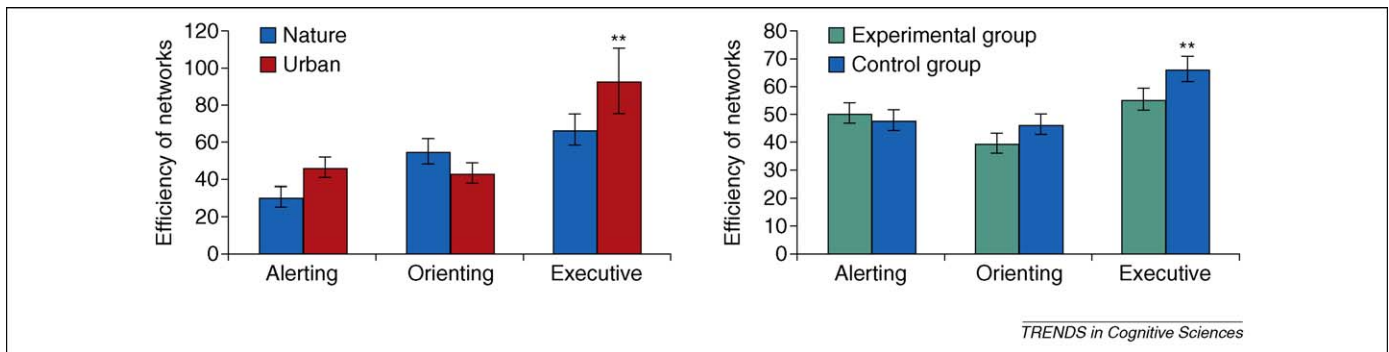


Figure 1. Attentional networks comparison for exposure to nature and IBMT. (a) Performance on the ANT after exposure to nature scenes or exposure to urban scenes, N=12, [14]. (b) Performance on the ANT after IBMT or relaxation control, N=40, [15]. The vertical axis indicates the difference in mean RTs for alerting, orienting and conflict scores. For conflict score, the higher score shows less efficient performance. Bars indicate ± 1 standard error.

and these generalized widely to other domains, such as inhibitory control and working memory [1].

Experiments involving working memory training have been carried out with older children who have been diagnosed with attention deficit hyperactivity disorder (ADHD) [12]. Training working memory not only improved that function but improvements were also found in an IQ test based on the Ravens Progressive Matrices Test.

Adult AT studies

Because attentional networks often show rapid development during childhood [4], improved performance due to AT might be expected to be confined to children, but that proved not to be the case. One adult study compared habitual video-game (except violent action game) players and non-players, finding that action-video-game players

had improved ability to take in and manipulate visual information [2]. This finding was confirmed with a ten-hour training study in which students randomly assigned to video games out-performed controls in several visual tasks, including improved visual resolution [9].

Recently it has been shown that working memory training in adults can generalize to other cognitive tasks. One study demonstrated adult improvement in more general cognitive abilities (fluid intelligence) after practice on a working memory task [3]. The extent of gain in intelligence depended on the amount of training.

Findings in a variety of functional magnetic resonance imaging (fMRI) studies of overlapping activation in ventral lateral prefrontal cortex (PFC) during memory tasks indicated that the memory tasks share common executive components [3,10,34]. One training regimen of working memory tasks and a set of transfer tasks were developed to examine the trainability of executive control process [10]. The study was unique in choosing to train a brain area already shown to be activated by tasks sharing a common executive component. Results indicated that executive control can be improved by working memory training and that this transfers to a wide variety of tasks.

Overall, these results establish that training of attention is possible in children and adults, improving attention and working memory and IQ tests measuring aspects of performance quite different from those involved in the training. There is no evidence thus far that this training improves self- or parent-reported moods or behaviors. This difference between cognitive and emotional changes, however, might be because of the fact that investigators have usually only tested cognitive tasks.

AST

AST refers to changes in state that accompany certain forms of experience such as meditation or exposure to nature. These methods have in common an altered state of mind and body but they use different sensory inputs to achieve their effects on mind and body and improve performance. Several of these studies have used randomized assignment between experimental and control groups and often they have used cognitive assays that overlap those used in AT tasks. They also include measures of self-regulation such as mood and response to stress [13–15].

Box 1. ANT

- ANT is an attentional assay that uses the Ericksen flanker task [5] as a target [6] (Figure 1).
- The ANT requires participants to determine whether a central arrow points left or right. Participants press the left key if the central arrows point left and the right key if they point right.
- Prior to a target, cues are used to provide information about when and where the target will be presented.
- Three subtractions provide scores for alerting, orienting and time to resolve conflict (executive attention). The measure of the efficiency of conflict resolution (executive attention) is given by subtracting the congruent RTs from the incongruent RTs. The alerting measure is given by subtracting the double cue (asterisks above and below fixation) from the no cue condition; the orienting measure by subtracting the RTs when the cue is at the target location from those where it is presented at fixation.

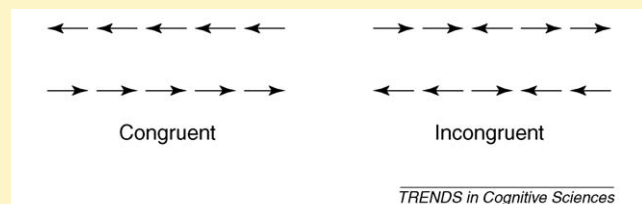


Figure 1. The Ericksen flanker task is a paradigm in which participants are asked to respond to a centered and directed item surrounded or flanked by distracting symbols like arrows or letters. Congruent flanking arrows all point in the same direction; incongruent flanking arrows point in different directions. Congruency affects the speed and accuracy with which the task is performed.

Exposure to nature

When people are required to focus their attention and put forth sustained cognitive effort, there is a possibility of mental fatigue. Attention restoration theory was proposed by Kaplan [16,17] to highlight the benefits of exposure to nature to restore directed attention. Mental restoration seems to work by encouraging a period of higher levels of involuntary attention, while decreasing directed, voluntary attention to restore efficient mental effort [16,17]. Recent psychological studies comparing an experimental group exposed to pictorial scenes of nature with a control group exposed to urban scenes indicated that interacting with nature improves executive attention (Figure 1a). Figure 1 shows improvement (reduced reaction time [RT] to resolve conflict in the ANT) in executive attention after exposure to nature compared to an urban scene. No differences in self-reported mood were found because of training [14].

The mechanism for improved attention after nature exposure was thought to be because of a state change restoring attentional efficiency [14,16]. Recent studies [18,19] have shown that performing mental tasks involving cognitive control can lead to a reduction in systemic glucose. Replenishment of glucose leads to a return to high levels of performance. These data indicate that sustained mental effort can produce a state of fatigue that influences performance. It would be useful to test further the possibility that increased glucose is one mechanism for the restoration of attention after exposure to nature.

Mindfulness

Mindfulness is awareness of one's present thoughts, emotions or actions. Mindfulness training involves bringing one's awareness back from the past or the future into the present moment. Many studies have shown the training effects of mindfulness, including reduced pain and stress, improvement of cognitive functioning and positive emotion [20–23]. Mindfulness requires awareness of the present moment and focuses mainly on changes in the state of the mind. One study observed changes in performance on the second of two repeated target stimuli during rapid visual presentation [24]. Failure of people to detect a second target soon after the first has been called 'the attentional blink'. Three months of intensive mental training resulted in improved second target detection (reduced attentional blink) and also reduced brain-resource allocation to the first target, indicating that mental training can result in increased control over the distribution of limited brain resources, resulting in an improvement in the executive attention network [24].

IBMT

IBMT was adopted from traditional Chinese medicine and incorporates aspects of meditation and mindfulness training. However, IBMT views cooperation between the body and mind as important. This meditative state is difficult to achieve unless there is a balance and optimization of mind and body [15,25,26]. IBMT is designed to facilitate the achievement of this balanced state and maintain it to improve attention and performance.

In one study [15], Chinese undergraduates were randomly assigned to an experimental group or a control group

for 5 days of short-term training (20 min per day). Students were given IBMT (experimental group) or relaxation training (control group). Training was presented in a standardized way via a CD and guided by a skillful IBMT coach whose job was to make sure of quality training in each session. The two groups were given a battery of tests before training and after the final training session. The IBMT group showed significantly greater improvement of performance in executive attention using the ANT (Figure 1b). They also showed lower anxiety, depression, anger and fatigue, and higher vigor on the Profile of Mood States scale, in addition to significantly reduced stress as measured by cortisol secretion after a stressful experience and increased immunoreactivity [15].

IBMT does not stress efforts to control thoughts, but instead induces a state of restful alertness, enabling a high degree of awareness of body, mind and external instructions. It seeks a balanced state of relaxation while focusing attention. Control of thought is achieved gradually through posture and relaxation. The coach works to achieve a balanced and harmonious state rather than by having the trainee attempt an internal struggle to control thoughts in accordance with instruction.

In short, IBMT improves attention and self-regulation through state changes involving both body and mind. Training leads to better performance in cognition, emotion and social behaviors [15]. The combined use of body and mind training is also supported by studies of embodied cognition, in which changes in the body, particularly in facial expression, influence emotional processing and facilitate retrieval of autobiographical memories [25,26].

Interaction within AST streams

AST has a long history worldwide but seldom draws great attention in the scientific community. Being in harmony with nature is the central life attitude and philosophical idea in Chinese and Eastern cultures. For many hundreds of years, practitioners chose natural environments such as parks, forests and mountains to practice body and mind training such as Tai Chi, Yoga, martial arts and meditation. In the West, walking or hiking in nature, doing exercise and vacationing in national parks are popular activities that attract many millions of people.

AST includes several stages. The early stage involves mental restoration, releasing fatigue to perform attentional and related cognitive tasks effectively. IBMT and exposure to nature share this stage. The most important difference between IBMT and nature exposure is whether one has a cumulative set of experiences that produce a deeper body-mind state in each session. In nature exposure, the eyes are open, making it more difficult for a novice to get into a deeper mental state, whereas for the IBMT practitioner the eyes are closed and different techniques such as breath adjustment and mental imagery are used in each session to produce an increasingly deep mental state.

After continued practice, a stage of improved performance is commonly obtained in which subjects reach a comfortable equilibrium, triggering the autonomic nervous system (ANS) to further regulate the brain. The role of ANS has received support from brain imaging studies

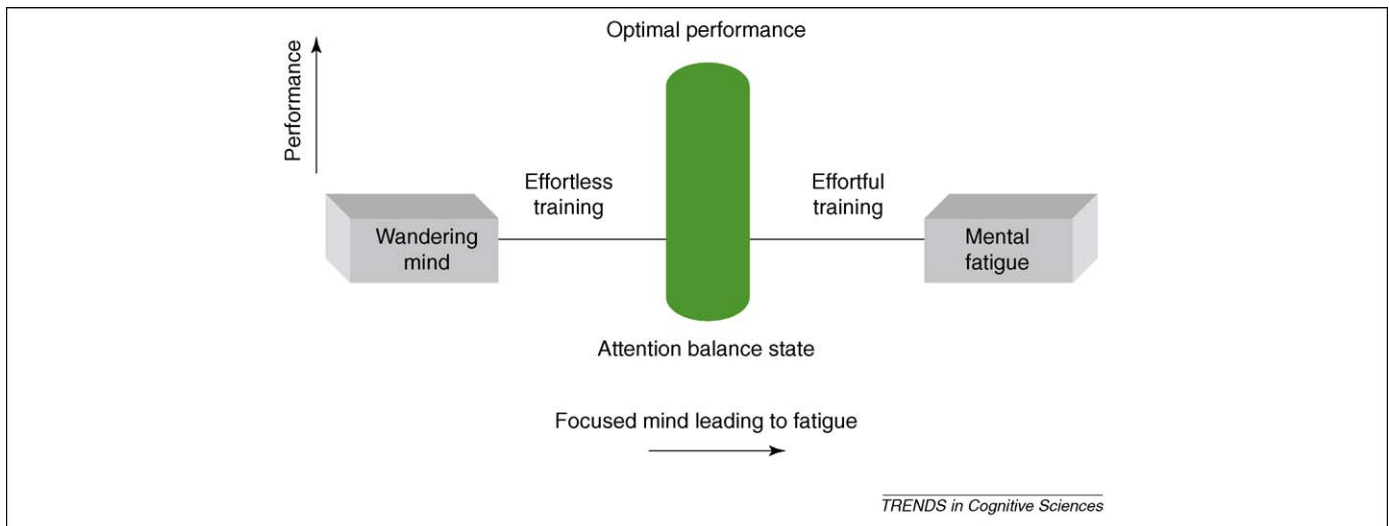


Figure 2. AT, AST and performance mind wandering and mental fatigue are two extremes of the untrained mind (left and right gray rectangles). AT requires effortful control to improve performance whereas AST changes body-mind state through effortless practice. Optimal balance (attention balance state) is hypothesized to trigger the most efficient performance (middle cylinder area).

showing a close connection between the anterior cingulate cortex and autonomic control [27,28].

In one Chinese study, it was shown that IBMT reduces cortisol secretion in response to stress in a dose dependent manner after between 5 days and one month of training [29]. After one month of training, the baseline of cortisol seems to have been reduced. It is not clear whether other forms of AT or AST would have similar effects and this possibility warrants further exploration.

A natural tendency of the mind is to be restless, that is, to wander as the focus of attention is switched. AT directly exercises the executive control networks. Because control increases mental effort, its overuse often leads to mental fatigue. Figure 2 summarizes the relationship between a state in which the mind is wandering freely at one extreme, to a state of fatigue at the other. The goal of AST is to produce an optimal balance (attention balance state) between the two extremes. This state is also thought to produce better performance.

Brain mechanisms

AT mechanism

Imaging studies of AT are limited so our discussion of the neural mechanisms involved is speculative, but can yield testable hypotheses. In an fMRI study of conflict tasks such as the ANT, but without training, the ability to resolve conflict activates both midline frontal activity (anterior cingulate cortex) and lateral PFC [30,31].

Rueda *et al.* [4] used high density electroencephalography (EEG) before and after AT. A child version of the ANT was used with 4- and 6-year-old children, and the results were compared with adult EEG. It was found that the trained 6-year-old children showed an adult pattern of greater negativity following incongruent than congruent flankers over midfrontal electrodes after training. In adults, this EEG pattern has been associated with activity in the dorsal anterior cingulate [32]. No such activity was found in 6-year-olds before training or in 4-year-olds either before or after training.

The working memory method used to train children with ADHD was used in an fMRI study to examine areas of brain activity that changed after five weeks of training [33,34]. Several areas of the lateral PFC were increased in activity after training.

One fMRI study of the attention network task [35] showed that the task produced increases in connectivity between the dorsal anterior cingulate cortex (ACC) and lateral PFC during performance. This suggests that the ANT might involve both midline and lateral areas during task performance. However, this study did not involve any explicit training.

Overall there is some evidence that AT involves changes in anterior cingulate and lateral prefrontal areas, perhaps mainly through increased connectivity between the two. Further research is needed to examine brain changes during AT and particularly connectivity changes between frontal areas.

The different roles of ACC and PFC in AST

Recent studies have involved 2-week and 4-week long practice of IBMT. In comparison with a relaxation control group, the IBMT group showed increased ACC involvement during a resting condition [29,36]. This increase in activity in the ACC is similar to what is found in AT during task performance and could account for the improved executive attention with both methods. In the IBMT studies, measures of heart rate variability reflecting ANS activity and regulation were correlated with frontal midline theta activity recorded from scalp electrodes. Because midline theta has been associated with autonomic control [37,38], these results indicate the importance of both the central nervous system and the ANS as mechanisms for improved performance after IBMT.

In his book on mindfulness, Siegel [39] suggests that when midline cortical regions (e.g. the anterior cingulate) are engaged without activation of lateral prefrontal areas involved in working memory, a mindful state might be obtained without effort [39]. IBMT practice has been

described as proceeding from effortful practice to effortless practice. In initial stages, a practitioner devotes mental effort to enter into a quiet and relaxed state quite different from his or her daily life, with restless wandering thoughts and diverse emotions. This requires strong executive function and capacity that heavily involves the PFC.

With practice, the practitioner experiences a deeply relaxed state, entering the mid-stage of meditation. The process still requires effortful control, but at this stage the ANS starts to work in parallel. Because the ACC has been implicated in self-regulation [40] and is also important in regulation of autonomic activity [27], we speculate that the ACC has an important role in this stage to maintain the balance of cognitive control and autonomic activity. In later meditation stages, the practitioner does not need strong effort and uses only effortless experience to maintain the meditative state. When deeply in this state, practitioners totally forget the body, the self and the environment. In this stage, the ANS is in control and ACC activity should be dominant [41]. We speculate that it is these deeper late stages of meditation that differ most clearly from AT. More research will be needed to test these hypotheses.

Future directions

The methods we have discussed for AT and for AST (see Box 2 for a brief summary of the main features of each method) are certainly not the only ones available. Instead, they represent examples of methods that have been rigorously tested. It seems likely that AT is a consequence of deep and sustained work in any subject. Some subjects, for example music and art, absorb the interest of children and the lessons serve as vehicles for training attention; strong executive

Box 2. Comparing features of AT with AST

AT

- Trains executive attention networks
- Requires directed attention and effortful control
- Targets non-autonomic control systems
- Produces mental fatigue easily
- Training transfers to other cognitive abilities

AST

- Produces changes of body-mind state
- Requires effortful control (early stage) and effortless exercise (later)
- Involves the autonomic system
- Aims at achieving a relaxed and balanced state
- Training transfers to cognition, emotion and social behaviors

Box 3. Outstanding questions

- Which factors help to facilitate the optimal body-mind state?
- Are there critical ages and training lengths for AT and AST?
- What is the optimal dose of particular types of AT and AST at different ages?
- What are the peripheral biological consequences of different forms of AT and AST?
- How might individual differences be matched to AT and AST methods?
- How could the optimal state be maintained?
- Which aspects of AT and AST affect education, professional performance and social behaviors?

attention serves to enhance development of other cognitive processes [42]. It seems likely that other methods of quieting and directing the mind serves to change state. These topics would need to be explored in future studies (Box 3).

Paying attention has a very important role in school performance and education. AT exercises executive control and transfers to cognitive capacities for learning, and adding AT to pre-school classroom work has been shown to improve students' cognitive control [1]. AST in children has also been shown to facilitate learning and improve cognition, emotion and performance [29,36]. These two types of training influence somewhat different brain networks and in future studies they might be combined to enhance their effectiveness. Future studies could also shed light on how to design training appropriately for persons differing in temperament or learning style.

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