# Yoga and Brain Function

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## Abstract

Yoga and mindfulness meditation have long been studied for their improvements on mental health and mental illness. This project proposed an experiment to investigate the effectiveness of yoga and mindfulness meditation on cognitive ability of college students. The voluntary participants were categorized into control, meditation and yoga group for a 4-week study. AX-CPT and O-SPAN tests were conducted after each of the meditation/yoga session to test their cognitive control, working memory and response time. Although the number of participants were significantly reduced due to external factors, the result still shows a tendency of enhancement of response time of meditation in a short period, while other effects are not observed.

# Table of Contents

# 1. Introduction

Nowadays mindfulness meditation and yoga have a great popularity in society due to their benefits to both mind and body. Many studies have shown their connections to improvements in cognitive ability, mental illness and various psychological issues. The purpose of this project is to find potential benefits of Meditation and Yoga on college students in two category of brain function: cognitive control and working memory. It is worth noting that due to some reason there weren't enough volunteers recruited and most of the recruited withdrew in the middle of the study. The remaining data, although incomplete of making any statistical conclusion, might as well lead to interesting observations and additional investigations.

In this report the background information about cognitive ability, cognitive control, meditation and yoga (the origin, history and effects) will be given before details of the experiment design and execution were discussed. All the data from the experiment will show in graph and the results will be discussed.

# 2. Background Information

## 2.1 Brain Function

### 2.1.1 Cognitive Ability

#### 2.1.1.1 General cognitive ability

General cognitive ability is basically the ability to learn (Hunter, 1986, as cited in Schmidt, 2002). From the point of view of public relations, it is unfortunate that psychologists sometimes refer to GCA as intelligence, as this term implies genetic potential for laymen and not the idea of developed ability at the time when the test is conducted that psychologists actually refer to it (Schmidt, 2002). This semantic bewilderment brings out reluctance to acknowledge results from studies while the word g refers to developed GCA rather than genetic potential (Schmidt, 2002). The fact that GCA scores even are strongly affected by genes does not alter the fact that GCA scores represent more than just genetic potential (Schmidt, 2002).

Certain cognitive process in the working memory system that are considered to be related to general cognitive capacity (Rohde, 2007). A few researchers argue that the bridge between working memory and general cognitive capacity is the speed of cognitive processing (Rohde, 2007). Vernon (1983) indicates that the link between processing speed and general cognitive capacity shows individual differences in the limitations of working memory components (Rohde, 2007). Developmental research suggests a combination of working memory and processing speed is needed to demonstrate the individual difference in general cognitive capacity (Fry & Hale 1996, as cited in Rohde, 2007). Some other particular cognitive abilities could also be studied in addition to processing speed and working memory to find out their significance for individual differences in psychometric 'g' (Rohde, 2007).

Spatial capability is also an important frame for general cognitive ability (Rohde, 2007). Spatial ability was identified as a form of visual perception or sensory input involving mental manipulation or rotation in the orientation or location of objects or shapes within a given area or space (Carroll, 1993, pp. 304–310, as cited in Rohde, 2007). Stumpf (1994) found that spatial capacity subtypes were capable of predicting performance in accelerated mathematics courses offered to talented individuals (Rohde, 2007). Baddeley and Logie (1999) indicated that working memory covers many distinct cognitive skills including: verbal ability, spatial ability, long-term memory retrieval, and executive functioning, of course (Rohde, 2007). The theoretical model of Logie (1995) represents working memory, long-term memory retrieval, and sensory inputs such as spatial ability as separable cognitive processes that can account for unique variance in general cognitive ability individually (Rohde, 2007). Johnson and Bouchard (2005) go one step further and propose a human intelligence structural model that includes image rotation as one of the three main factors of general cognitive ability (Rohde, 2007).

Luo and Petrill (1999) selected basic cognitive tasks to test whether or not the speed of information processing or memory processing are intrinsic parts of general cognitive ability by using exploratory and confirmatory factor analysis (Rohde, 2007). Their results revealed that a mixture of basic cognitive tasks and standard psychometric tests of general cognitive ability can be classified as general cognitive ability without altering the nature of the relationship between' g' and academic achievement(Rohde, 2007). In addition, a learning and memory function consisting of non-chronometric variables was highly related but independent of the general aspect of information processing (Rohde, 2007). This result led the researchers to believe that the relationship between the learning and memory component and general cognitive capacity could tap into some dimension of information processing and memory that is not linked to information processing speed (Rohde, 2007).

#### 2.1.1.2 Cognitive ability and genetics

General cognitive ability is highly controversial for historical and political reasons, it has a normal population distribution from a low end of mild mental disability to a high end of gifted people (Plomin, 2002) . Various cognitive ability measurements, such as spatial ability, verbal ability, speed and memory information processing — substantially correlate with each other, and general cognitive ability (g) is what these various measures have in common (Plomin, 2002) . There is obviously more to cognition than g, though g explains around 40% of the variance among such tests, most of the variance of a particular test is independent of g (Plomin, 2002) . There is a wide gap between what lay people believe about intelligence and intelligence testing (including scientists in other fields) and what the professional behavioral scientist believes (Plomin, 2002) . In the popular press, most notably, lay people often read that intelligence assessment is circular, as intelligence is what intelligence tests evaluate (Plomin, 2002) . In the contrast, g is one of the behavioral domain's most reliable and valid measures (Plomin, 2002) ; its long-term after childhood stability is greater than any other behavioral trait, and it predicts significant social outcomes such as academic and occupational levels much better than any other trait (Plomin, 2002) . Although there are still a few opponents, experts generally support g (Plomin, 2002) . But whether or not g is due to a single general mechanism like high-level techniques called executive function or speed of information processing is less clear.

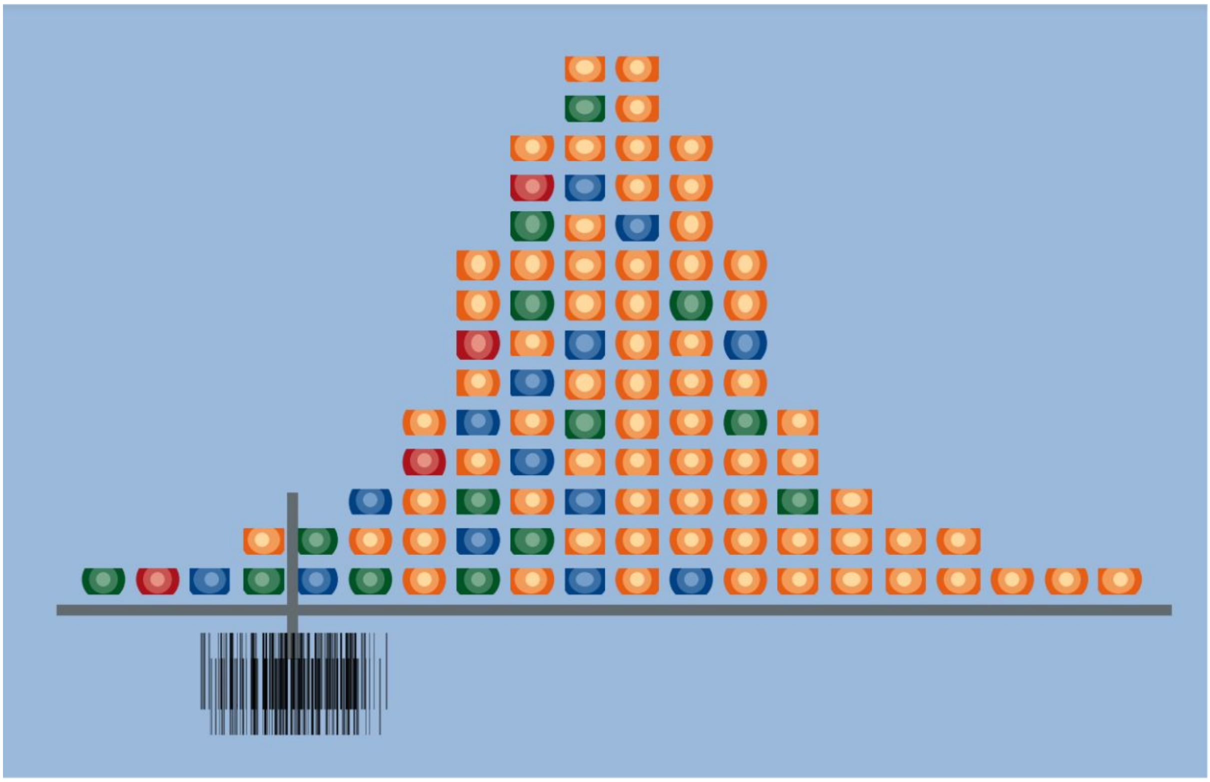

**Figure 1.** Quantitative trait locus (QTL) perspective on complex traits (Plomin, 2002).

Differences among individuals are distributed as a normal bell-shaped curve for most quantitative or complex features such as reading ability (Plomin, 2002) . Multiple genes influence complex traits rather than predetermined programs as probabilistic propensities(Plomin, 2002) . The different genetic make-up of individuals with respect to two hypothetical genes involved in reading ability is shown for 100 individuals (each person is represented by an oval), with five of those individuals (those on the extreme left) receiving a diagnosis of reading disability(Plomin, 2002) . The green ovals indicate that the individual has one gene's disabled variant and the other gene's disabled variant is denoted by the blue ovals (Plomin, 2002). For low scores, neither gene is necessary or sufficient, even for people with disabling variants of both genes (red ovals) (Plomin, 2002) . This QTL perspective suggests that genes associated with common disorders such as disability in reading might represent the quantitative extreme of the same genes that are responsible for variation throughout the population (Plomin, 2002).

Most of the genetic variance for g is additive, that is, the effects of the individual genes seem simply to add up rather than there being interactions between the genes (Plomin, 2002) .

Some genetic effects on g may be additive because there is more assortative mating for g than any other behavioral trait (Plomin, 2002) . In other words, bright women are likely to match bright men, and the result of this dual effect is that their offspring are likely to be brighter on average than would be expected if they match at random, thereby spreading the distribution of g in the population (Plomin, 2002). Genetic research has gone beyond the basic questions of whether and to what extent genetic differences are important in the origins of individual differences in g (Plomin, 2002).

#### 2.1.1.3 Cognitive ability and academic achievement

Luo, Thompson and Detterman (2003) tested the hypothesis that the interrelationship between psychometric' g' and academic achievement was largely associated with the element of mental speed. Initially, the shared difference between general intelligence and academic achievement was about 30% (Rohde, 2007). Nevertheless, the shared variance between psychometric' g' and academic achievement was reduced to around 6 percent after accounting for the mental speed component (Luo et al., 2003, as cited in Rohde, 2007). This result is strong evidence that a significant mediator between psychometric' g' and academic achievement is the mental speed component (Rohde, 2007).

Academic achievement scores for high school students correspond with IQ scores between .50 and.70 (Jensen, 1998, as cited in Rohde, 2007) and results on standardized academic achievement tests can be used to accurately estimate IQ scores (Frey & Detterman, 2004, as cited in Rohde, 2007). While there is empirical evidence of a strong association between general cognitive ability and academic achievement, there is still from 51% to 75% of the variation in academic achievement that is not accounted for by general cognitive ability tests alone (Rohde, 2007). In addition, recognizing the nature of the relationship between general cognitive capacity and academic achievement has wide-ranging consequences for both theory and practice (Rohde, 2007). Some unique cognitive abilities have the potential to further comprehending the general cognitive capacity components (Rohde, 2007). Recent research focused on delineating the general cognitive skill framework has aimed to define separable structures to describe individual differences in psychometric 'g' (Rohde, 2007). These same concepts may also be applicable to academic achievement comprehension (Rohde, 2007). For example, the theory of information processing suggests that a large portion of the individual differences in' g' can account for overall mental efficiency (Vernon, 1983; Rohde, 2007). Processing speed and working memory are two cognitive processes used to explain what drives mental efficiency and therefore general cognitive ability (Rohde, 2007).

On the contrary, the broad literature on' g' defines general cognitive ability and academic achievement as two constructs that are strongly related but distinct (Rohde, 2007). An important fact to note about the relationship between general cognitive ability and academic achievement is that they can not predict one another perfectly (Rohde, 2007). Actually, measures of general cognitive ability alone can not account for more than 50 percent of the variance in academic achievement (Jensen, 1998). While the significant amount of mutual variation between these concepts is well known in the literature, assuming that they are identical may not be appropriate (Rohde, 2007).

#### 2.1.1.4 Cognitive ability and job performance

In the range of cognitive abilities the so called Specific aptitudes are narrower than GCA (Schmidt, 2002). This  includes verbal aptitudes, numerical aptitudes and spatial aptitudes (Schmidt, 2002). It was widely believed that the use of a number of aptitude tests could better predict job performance than using GCA alone and multiple aptitude theory proposed that different jobs required different aptitude profiles and that regression formulas with different aptitudes for different jobs should improve performance prediction at work and in training (Schmidt, 2002). Although this hypothesis had a convincing plausibility for most citizens, it was disconfirmed (Schmidt, 2002). Multiple aptitude tests weighing differently produces little or no increase in validity over the use of general mental ability measurements (Schmidt, 2002). Aptitude tests have been found to mostly measure GCA; besides, each measure something specific to that aptitude (e.g., specifically numerical aptitude, above and beyond GCA) (Schmidt, 2002). The GCA component appears to be responsible for predicting job performance and training, while aptitude-specific factors seem to contribute little or nothing to predicting (Schmidt, 2002).

Based on meta-analysis of more than 400 studies, Hunter and Hunter (1984) calculated the reliability of GCA for overall job quality supervisor scores to be 0.57 for highly complex jobs (about 17% of U.S. jobs), 0.51 for medium-complex jobs (63% of jobs), and 0.38 for low-complex jobs (20% of jobs). Such findings are consistent with those from other sources

(Hunter & Schmidt, 1996). There are a number of large databases for performance in job training programs, many based on military training programs. Hunter (1986) reviewed military databases for more than 82,000 trainees and found an average GCA validity of.63 (Schmidt, 2002).

### 2.1.2 Working Memory

#### 2.1.2.1 Introduction

Working memory (WM) is the ability to keep data stored for a short time (Goldman-Rakic, 1987, as cited in Westerberg, 2004) and is believed to underpin a wide range of mental tasks, such as reading, arithmetic, and problem solving (Barkley, 1997, as cited in Westerberg, 2004). However, WM has been shown to be critical in keeping test-specific information prioritized and thereby increasing disturbances from irrelevant stimuli (de Fockert, Rees, Frith, & Lavie, 2001, as cited in Westerberg, 2004).

Working memory capacity is a critical cognitive feature, and one's ability has a significant impact on cognitive performance quality (Conway, 2003). Some authors also say that the most important factor in general fluid intelligence is working memory capacity (Kyllonen, 1996, as cited in Conway, 2003).

Different theories illustrate various aspects of the structure of working memory(Oberauer, 2000). The facet theory acts as a method for these things being systematized(Oberauer, 2000). The resulting facet schema forms a theoretical framework for working memory ability that through structural analysis techniques can be checked against the information(Oberauer, 2000). Working memory in this concept is divided between two dimensions, one representing the working memory resource variable, the other the task material information domain(Oberauer, 2000). There are three groups in each dimension. It is classified into verbal, numerical, and spatial working memory on the content facet(Oberauer, 2000). The functional aspect categories represent the three main functions that are assigned in the literature to the working memory: simultaneous processing and manipulation, monitoring (or executive control) and coordination(Oberauer, 2000). (Oberauer)

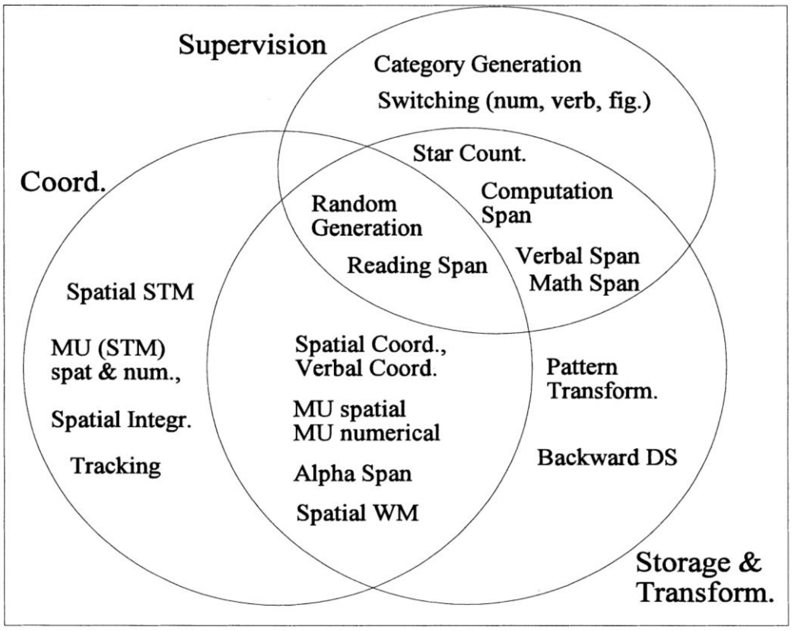


**Figure 2.** Classification of working memory tasks into three overlapping functional categories.(Oberauer,2000)

### 2.1.2.2 Working memory capacity and its relation to general intelligence

Early research into working memory capacity (WMC) and reasoning ability suggested that WMC could form the basis of Spearman's g (Conway, 2003). However, studies has revealed details of the basic processes involved in working memory tasks, resulting in a more principled approach to task development (Conway, 2003). As a result, there are now more cautious claims about the relationship between WMC and g (Conway, 2003). WMC and g are highly related, but not the same (Conway, 2003). In contrast, WM period tasks include an executive-control mechanism hired to combat interference, which is mediated by parts of the prefrontal cortex(Conway, 2003). More experimental-differential research is needed to better understand the basis of the relationship between WMC and g (Conway, 2003).

Latent variables provide a cleaner measure of the structure under investigation, thus providing the clearest picture of the true relationship between WMC and g (Conway, 2003). The first latent variable study of individual differences in WMC and g was developed by Kyllonen and Christal and showed strong associations (near unity) between WMC and reasoning ability (Conway, 2003).

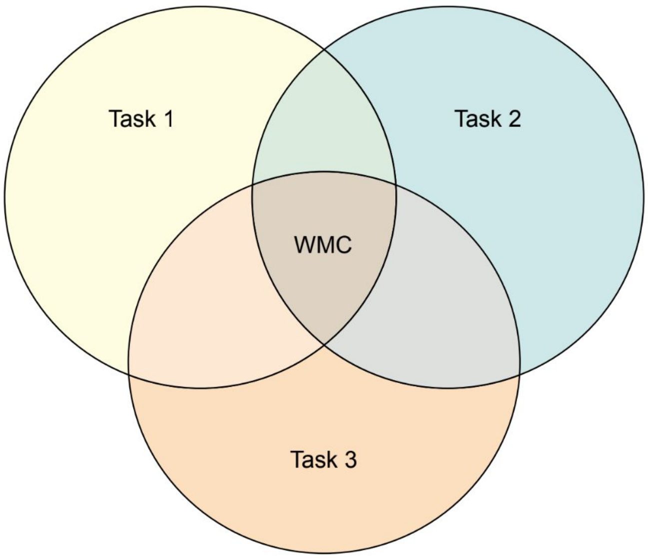


**Figure 3.** A venn-diagram of the relationship between three tasks involving working memory capability (WMC). When the task-specific variance is eliminated, the typical variance reflects the latent variable (e.g. WMC) (Conway, 2003).

Latent variable modeling, also known as structural equation modeling (latent variable models with causal paths among latent variables) and confirmatory factor analysis (latent variable models without causal paths among latent variables) involves multiple tests for each theoretical construct (e.g. working memory power, g) being applied to a large number of subjects, usually 100 (Conway, 2003). The measures or functions observed are called manifest variables (Conway, 2003). Latent variables are derived from the covariance between manifest variables that calculate the same construct (Conway, 2003). In other words, latent variables are variances that are shared among all the tasks used to define the construction (Conway, 2003). As such, the task-specific variation is excluded, which is unique to each task, resulting in a relatively pure measure of the latent construct of interest (Conway, 2003).

### 2.1.2.3 Working memory capacity and the cocktail party phenomenon

The capacity to suppress disruptive data (Dempster, 1991) is a fundamental aspect of intelligent behavior related to working memory (Conway, 2003). While the current study does not provide direct evidence of information inhibition provided in the irrelevant flow, the perception that high-span subjects are better at distracting information than low-span subjects is consistent with previous studies (Conway, 2003). For example, multiple studies have shown in the context of memory retrieval that high-span subjects are more likely to reveal inhibition effects of retrieval and therefore less constructive intervention than low-span subjects (Conway & Engle, 1994; Kane & Engle, 2000). The negative priming effect is also consistently revealed by high-span subjects, while low-span subjects do not (Conway et al., 1999). Whether or not an inhibitory mechanism is required to account for these results, it is clear that the ability to handle cognitive intrusion is a factor which varies between individuals with high and low-work memory spans (Conway, 2003).

Wood and Cowan (1995) repeated and expanded Moray's (1959) research into the phenomenon of the cocktail party, referring to a situation where only part of a noisy environment can be attended to, but highly relevant stimuli such as one's own name can unexpectedly catch focus (Conway, 2003). Both of these previous investigations showed that in an unattended, irrelevant message about 33 percent of subjects report hearing their own name (Conway, 2003). Subjects that detect their name in the irrelevant message have relatively low working memory capacity, suggesting that they have difficulty blocking or inhibiting information that distracts them (Conway, 2003).

#### 2.1.2.4 Working memory as indices of cognitive skills

A more or less static short-term memory (STM) system and a more active working memory (WM) system are made experimental and theoretical distinctions(Hutton, 2001). Various tests have been designed to assess their efficiency, and research has generally shown that WM is a reliable predictor of general cognitive ability for adults, not STM. Nevertheless, little consideration has been paid to the locus of the discrepancies between the tasks(Hutton, 2001). Researchers provided in a study (Hutton) information from children on measurements of matrix reasoning ability, learning, and numerical skill along with forward and backward order sequential retrieval of WM, STM, and STM with articulatory suppression tasks(Hutton, 2001). STM and WM are similar in terms of memory per se as indices of the cognitive abilities of children(Hutton, 2001). Neither rehearsal ability nor task difficulty offers adequate explanations for memory test discrepancies(Hutton, 2001).

It seems that what holds in adults for WM may not be equally true in children, and vice versa(Hutton, 2001). A research (Hutton) highlights the importance of taking into account the on-line processing of children during WM activities, indicating that WM and STM may be quite similar among children, at least in some circumstances(Hutton, 2001). Data suggest that the position of discrepancies between STM and WM is not just a specific incentive for rehearsal, as curtailing rehearsal in STM makes the role more distinct than, and not more comparable to, WM. It appears that to understand the relationship between memory tasks, a more complete description of the scope of retention techniques and task characteristics is needed (Hutton, 2001). A simple dichotomy between STM and WM is a major oversimplification.

#### 2.1.2.5 Working Memory and ADHD

WM deficits could lead to greater distractibility in ADHD (Westerberg, 2004). Substantial research is being done on the neurophysiological substrates underlying WM activity, and these substrates, the most important of which seems to be the prefrontal cortex, correlate with those considered to be affected by ADHD (Westerberg, 2004). WM functioning is also well known to rely on dopamine (Williams & Goldman-Rakic, 1995, as cited in Westerberg, 2004), which is consistent with ADHD's association with atypical dopaminergic transmission (Cook et al., 1995, as cited in Westerberg, 2004). In addition, drugs such as methylphenidate and amphetamine, known to ameliorate the symptoms in ADHD, facilitate dopaminergic transmission (Volkow, 1995, as cited in Westerberg, 2004), and also improve WM (annock, Ickowicz, & Schachar, 1995, as cited in Westerberg, 2004). (Westerberg)

Throughout reaction time tests, it was proposed that the delay and variance of response distinguish between children with and without ADHD (Westerberg, 2004). In that selection of reaction time (CRT) tasks, this could possibly be related to WM, measuring speed of execution, which in turn could assess WM efficiency (Fry & Hale, 1996, as cited in Westerberg, 2004). Speed-of-processing would be more important in this respect, and measures like the CRT would be more sensitive than the WM test (Westerberg, 2004).

### 2.1.3 Cognitive Control

#### 2.1.3.1 Motivation and cognitive control

Cognitive control is a collection of superior functions that interpret, maintain and identify the current task or associated stimulus-response relationships, contingencies of action-outcome, and goal states or objectives (Botvinick, 2001). Subordinate tasks such as working, semantic and episodic memory; perceptual attention and response selection (Botvinick, 2001). Control status can be defined in (a) the particular task goals to which subordinate structures are directed; and (b) the strength of their top-down control feedback (Bonner & Sprinkle 2002, Shenhav et al. 2013, as cited in Botvinick, 2001).

The motivation-control interface has a number of key behavioral anomalies and can be grouped into three headings: (a) the effect on incentive control function, (b) the role of motivational factors in temporal dynamic control, and (c) the intrinsic cost of cognitive control (Botvinick, 2001).

In a remarkably diverse range of sub-fields of behavioral science, including cognitive psychology, social and personality psychology, behavioral economics, and self-control and behavioral energetic studies, the relationship between motivation and cognitive control was discussed (Botvinick, 2001).

Three basic theoretical approaches to the motivation-cognitive control relationship have been found, slicing across these areas (Botvinick, 2001). Someone is using a force-field metaphor. A second focuses on the concept of a limited capacity resource. The fifth views the subject in terms of reward-based decision-making (Botvinick, 2001).

#### 2.1.3.2 Computational models of cognitive control

In the absence of strong environmental assistance in the face of other stimuli or other types of intervention, cognitive control refers to the ability to perform task-relevant work (O'Reilly, 2010). This depends on the wholeness of the prefrontal cortex and associated biological structures (e.g. basal ganglia) (O'Reilly, 2010). Computational models played an important role in developing our comprehending of this system in three main areas: dynamic prefrontal representation gating, prefrontal cortex hierarchies, and prefrontal cortex reward, motivation, and goal-related processing (O'Reilly, 2010). In these and other areas, models are advancing the field further (O'Reilly, 2010).

For creating a clear link between biological mechanisms and the cognitive and behavioral phenomena they produce, computational models are essential (O'Reilly, 2010). In the area of cognitive control science, there is a rich history of computational modeling (e.g. the capacity to perform task-relevant thinking in the face of other inputs or in the absence of strong environmental support), which has tended to concentrate empirical and other theoretical work on specific biological mechanisms and operational functions (O'Reilly, 2010). For instance, early models showed how effective information maintenance in a working memory system can be accounted for in terms of reverberatory excitation among a collection of interconnected neurons (O'Reilly, 2010), and how this actively preserved information can provide a powerful' top-down bias' to influence processing across the brain (O'Reilly, 2010). These models echoed a growing research base from many methodologies and relative theoretical concepts to provide a consistent account of the participation of cognitive control of the prefrontal cortex (PFC)(O'Reilly, 2010). This work, highly influential in the field, is one of the most important success stories for the contributions to computational modeling approach(O'Reilly 2010).

Building on this first phase of synthesis, a new generation of computational models has enlarged the conceptual and functional frameworks to include many other mechanisms with which PFC interacts in order to achieve cognitive control and the contributions made by the PFC itself (O'Reilly, 2010).

A notable consensus has converged on the general idea that a significant cognitive control element is a complex gating mechanism that can decide when to update PFC representations to reflect new information (O'Reilly, 2010).

Hierarchies have been involved in models of behavior control for a long time (O'Reilly, 2010). Only recently, however, hierarchical models have made explicit contact with relevant rapidly accumulating neuroscientific data (O'Reilly, 2010). Convergent findings suggest a hierarchy structured along the posterior-anterior anatomical axis of the PFC with depictions of higher-level control supported by more anterior regions, aligned with the original ideas of Fuster (O'Reilly, 2010). However, the best way to characterize this hierarchy is still a matter of considerable discussion, and computational models provide some important insights (O'Reilly, 2010).

#### 2.1.3.3 The prefrontal cortex and cognitive control

The mechanism of cognitive control dynamic and often willful activity appears from interplay between millions of neurons long thought to be prefrontal cortex-dependent (Miller, 2000). Today, however, scientists are capable to discover their neural base (Miller, 2000). Nearly all expected behavior is learned and therefore depends on a cognitive system to achieve and implement the 'rules of the game' required for achieving a given goal in a given situation (Miller, 2000). Studies show that in the prefrontal cortex this mechanism plays a central role (Miller, 2000). This provides an architecture for integrating a variety of information that lays the groundwork for the various types of behavior observed in primates (Miller, 2000).

Individuals and other animals may respond to immediate and relevant sensory information more than reflexively (Miller, 2000). People engage in dynamic, omnipresent, goal-oriented activities that are often far-reaching (Miller, 2000). Humans have evolved mechanisms that, in accordance with our intentions, can bypass or enhance reflexive and repetitive responses to orchestrate behavior (Miller, 2000). Such mechanisms are commonly referred to as' cognitive' in nature and their function is to regulate for a common purpose lower-level sensory, memory and/or motor operations (Miller, 2000). Mental regulation is therefore necessary for what we find to be rational behaviour (Miller, 2000).

From their most important feature, insight into neural mechanisms for cognitive control can be extracted: they are sculpted by experience (Miller, 2000). Developing almost all planned activities is based on a cognitive framework that can absorb the game's rules— what goals are needed and what methods can be implied to achieve those goals (Miller, 2000). A key function of the cognitive control mediating neural circuitry is to recover the goal-relevant characteristics of our experiences (Miller, 2000). It was suggested that this process involves the prefrontal cortex centrally (Miller, 2000) . The prefrontal cortex (PFC) provides an optimal framework for synthesizing the variety of information that complex activity demands (Miller, 2000). Furthermore, the PFC has extensive projections back to these structures that can allow it to exert a' TOP-DOWN' impact on a wide range of brain processes (Miller, 2000). Nevertheless, the outcomes of PFC damage are most apparent when cognitive regulation is required (Miller, 2000).

Recent neurophisiological experiments in monkeys exploring the neural basis for cognitive control suggest that the main function of the PFC is to obtain regularity information through interactions and thus transmit rules that can be used to direct thought and action (Miller, 2000).

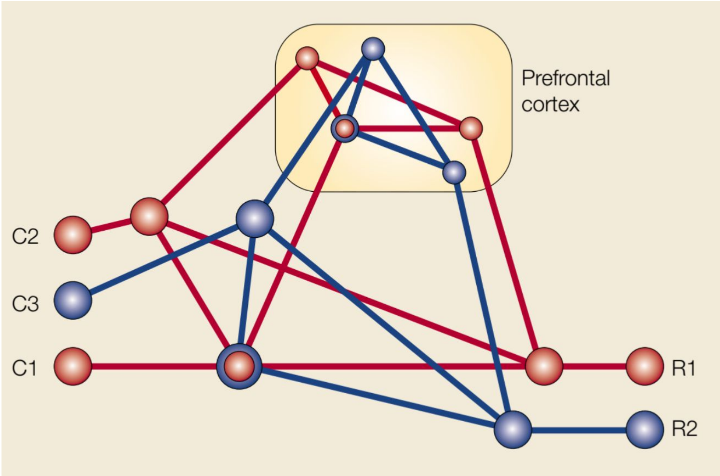


**Figure 4.** A suggested role for the prefrontal cortex in cognitive control. (Miller, 2000)

The figure shows processing units representing signals such as sensory inputs, current motivational state, memories, etc. (C1, C2 and C3) (Miller, 2000); units representing two voluntary actions (e.g. R1 and R2 responses) (Miller, 2000); and units of internal or secret representing intermediate processing phases (Miller, 2000). It is shown that the PFC is associated with the secret systems because it is associated with higher-order "association" and premotor cortices, not main sensory or motor cortices (Miller, 2000). A situation where the PFC seems to be particularly important is pictured here: if the same cue (C1) can lead to one or another response (R1 or R2) depending on some other element of knowledge (C2 or C3) (Miller, 2000). For example, if the phone rings (C1) and you're at home (C2), you'll answer (i.e., C1... R1) (Miller, 2000). But if the phone rings (C1) and you're a visitor in someone else's house (C3), you don't (C1... R2 (Miller, 2000)). When training, reward signals that reinforce the connections between PFC neurons which process information that leads to reward, resulting in a pattern of behavior which represents the pattern of associations between goal-relevant information specific to each situation (i.e. task contingencies) (Miller, 2000). Once formed, the entire representation will be triggered by a subset of information (e.g. C1 and C2) (e.g. the cluster of PFC's units shown in red), including data on the appropriate response (e.g. R1). Bias signals from the PFC task representations can then select task-relevant neural pathways in other brain structures (e.g. C1–R1). A different set of indications (C1 and C3) would activate a different PFC representation (shown in blue) and select a different set of neural pathways (C1–R2) from a different pattern of bias signals (Miller, 2000). The PFC supports the receptors in the rear neocortex and other brain areas suitable for the task by supplying a preference signal to the intermediate (hidden) groups (Miller, 2000). Because they rely on the current pattern of PFC activity, it is possible to dynamically and flexibly set up task-relevant pathways (Miller, 2000). A lack of mobility is a hallmark of PFC damage (Miller, 2000).

### 2.1.4 AX-CPT

#### 2.1.4.1 Introduction

The AX-CPT has been used in many studies and has been instrumental in developing a specific theoretical framework, known as the Dual Control Mechanisms (DMC; Braver et al., 2007; Braver, 2012, as cited in Cooper, 2017). The DMC model suggests that there are two approaches to apply cognitive control: proactive, where control is conducted in advance by constantly retaining contextual information, and reactive, where control is implemented after an event occurs (Cooper, 2017). One of the main assumptions of the DMC framework is that the proclivity of using proactive or reactive control is likely to have stable individual differences (Braver, 2012, as cited in Cooper, 2017). For example, young adults who are non-clinical in preference to apply proactive control (Braver, 2012, as cited in Cooper, 2017). In addition, other cognitive abilities that index how easily and flexibly one can maintain context information are likely to influence the ability and/or preference to use proactive control. For example, a participant with a lower average working memory capacity (WMC) may have difficulty consistently retaining context cues and thus be biased towards implementing reactive control strategies; whereas a participant with an above average WMC may not consider contextual data especially exhausting and may therefore be likely to use proactive control strategies (Cooper, 2017). Previous studies identified the association between performance on the AX-CPT (and similar tasks)  and individual differences in WMC (Redick, 2014; Richmond et al., 2015, as cited in Cooper, 2017), dynamic intelligence (Gray et al., 2003, as cited in Cooper, 2017), and even reward processing (Jimura et al., 2010, as cited in Cooper, 2017).

The AX-CPT is designed to measure cognitive control as to how context signals are actively maintained and used to respond directly to subsequent test items (Cooper, 2017). Participants are told to provide a specific response to a target sample and a different response to all non-target samples (Cooper, 2017). The target probe is the letter X, but only if the letter A as the background reference followed it (Cooper, 2017). It naturally leads to four types of trials: AX (target), AY, BX, and BY, where "B" represents any letter other than A, and "Y" is any letter other than X (Cooper, 2017). The classic AX-CPT model comprises 70% of AX tests and 10% of AY, BX, and BY trials (Braver et al., 2007, as cited in Cooper, 2017). More recent versions of the task used different proportions of trials (Richmond et al., 2015; Gonthier et al., 2016, as cited in Cooper, 2017), but always maintained the higher proportion of AX trials relative to AY and BX trials (Cooper, 2017). It produces a prepotent propensity to react to the goal after both A and X tests (Cooper, 2017).

Scientists use AX-CPT to analyze variations in constructive vs. reactive regulation by AY and BX analysis (Cooper, 2017). The context provided by the cue is particularly helpful to participants using adaptive regulation to respond correctly to BX trails, as the cue clearly decides that the task will be non-target (Cooper, 2017). However, a proactive strategy also leads to more AY errors because in the presence of an A-cue, participants often prepare incorrectly for a target probe (Cooper, 2017). On the other hand, AY trials are less difficult and BX trials are more complex for participants using reactive control because they do not deliberately plan a response during the interval between cue and probe (Cooper, 2017).

#### 2.1.4.2 AX-CPT in DMC framework

The primary hypothesis in the DMC paradigm is that a high contextual cue-based expectancy will be correlated with PROACTIVE regulation, particularly when the A-cue is introduced ("AX-CPT Task", n.d.). Prior research has shown that, through STRATEGY TRAINING procedures, these cue-based expectations can be enhanced (Paxton et al, 2006; Braver et al, 2009; Edwards et al, 2010, as cited in "AX-CPT Task", n.d.). These procedures highlight the differential expectations associated with each cue-type and encourage engagement during the CUE-PROBE DELAY INTERVAL in response preparation processes ("AX-CPT Task", n.d.).

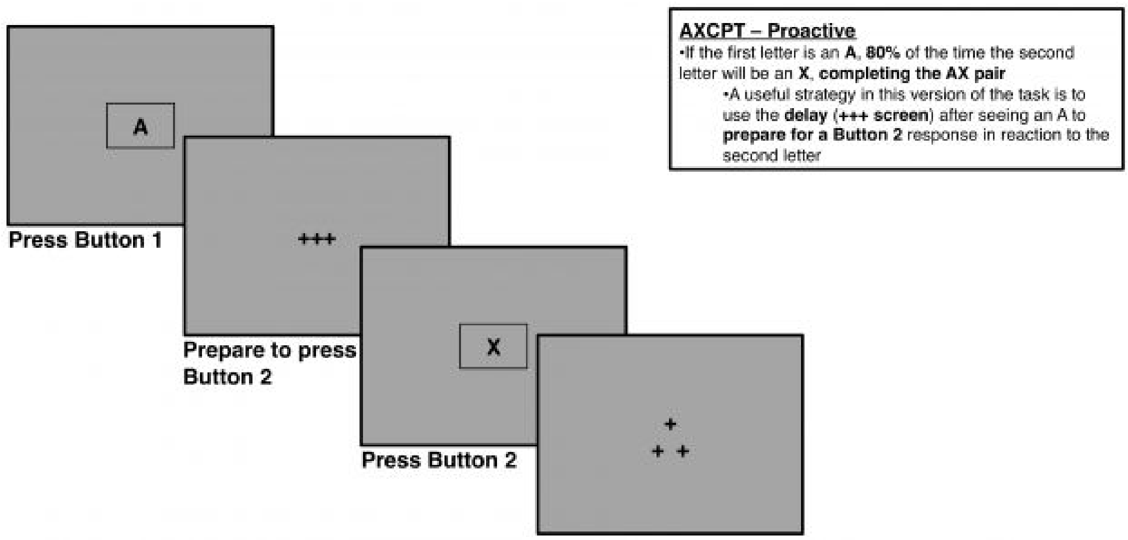


**Figure 5.** AX-CPT Proactive. ("AX-CPT Task", n.d.)

Nevertheless, proactive control biases are typically found in healthy young adults even without strategic training ("AX-CPT Task", n.d.). A new variant that involves NO-GO trials is used to eliminate these differences in the BASELINE condition (“AX-CPT Task”, n.d.). The increasing of no - go trials decreases the contextual cue's predictive validity, as the trial's no - go status can only be observed at the start of the investigation (“AX-CPT Task”, n.d.).

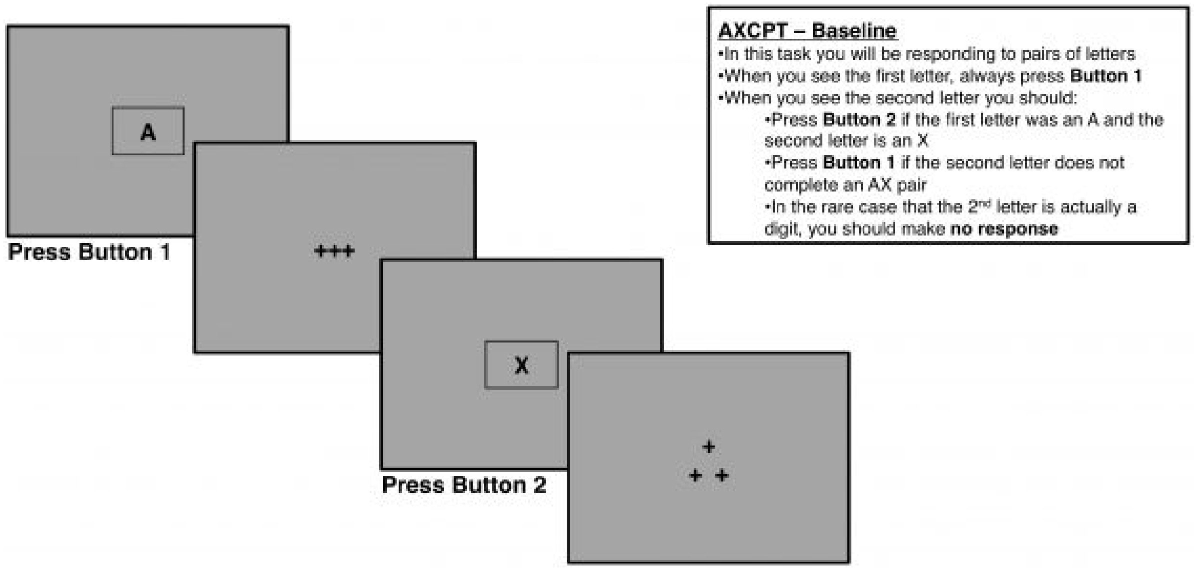


**Figure 6.** AX-CPT Baseline. (“AX-CPT Task”, n.d.)

A REACTIVE control strategy in the AX-CPT includes the use of probe identification and conflict in the DMC framework to facilitate context retrieval and selection of the appropriate response (“AX-CPT Task”, n.d.). Another variant in which LOCATION-COLOR PROBE-CUEING is included in order to improve reactive control (“AX-CPT Task”, n.d.). In this variant, probe stimuli are displayed for one spatial location and border color on low-conflict trial types (AX, BY), while high-conflict trial types (AY, BX, no-go) are presented in a separate spatial position and border color (“AX-CPT Task”, n.d.). The main logic behind this control is that cueing location-color does not define the stimuli or reaction of the probe individually, but it does show the trial's high vs. low conflict status (“AX-CPT Task”, n.d.). It should also promote contextual recall caused by conflict; but since cueing manipulation happens at the start of the probe rather than at the moment of cue, it should encourage a reactive rather than proactive task approach (“AX-CPT Task”, n.d.).

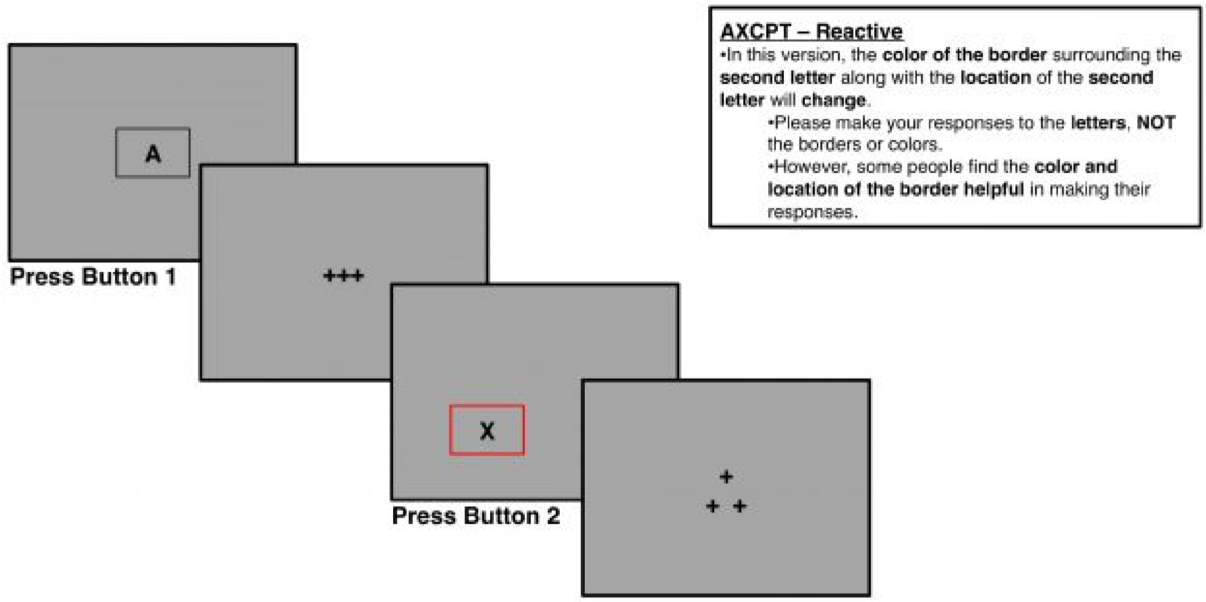


**Figure 7.** AX-CPT Reactive. ("AX-CPT Task", n.d.)

For no - go stimuli included, this condition uses the letter AX-CPT ("AX-CPT Task", n.d.). There are four different types of generic (go) tests: AX, AY, BX, and BY ("AX-CPT Task", n.d.). To ensure equal frequencies of A-cue and B-cue tests, the ratios of trail types are set ("AX-CPT Task", n.d.). The numerical percentages of these experiments refer to those used in Richmond et al (2015): 40% AX, 10% AY, 10% BX, 40% BY ("AX-CPT Task", n.d.). No - go stimuli occur at low frequency (16.7%) and are indicated by digit (1-9) instead of letter probes (which obey A-cue and B-cue contexts equally) ("AX-CPT Task", n.d.). Participants are instructed to refrain from response to these tests ("AX-CPT Task", n.d.). The time of cues and probes presents 500 msec ("AX-CPT Task", n.d.). The probes were surrounded by a rectangular white border, displayed 250 msec before the start of the test ("AX-CPT Task", n.d.).The delay period of the cue-probe is 4 seconds, putting instruction on maintenance target (context) processes ("AX-CPT Task", n.d.). There are 216 trails (72 AX, 18 AY, 18 BX, 72 BY, 18 A-nogo, 18 B-nogo) in the full condition ("AX-CPT Task", n.d.).

### 2.1.5 O-SPAN

#### 2.1.5.1 Introduction

The Turner and Engle (1989) Ospan task demands participants to solve a sequence of math operations while trying to remember a set of random words (Unsworth, 2005). During one time, the participants saw one math operation–word string based on a computer monitor (Unsworth, 2005). Participants had to read aloud to solve the math problem for each trial and then read the word aloud (Unsworth, 2005). The next operation-word strings was introduced directly after the participant read the word (Unsworth, 2005). The operation-word strings have been provided in sets of two to five items (Unsworth, 2005). The participant was told to remember the words in the order given after each complete set (Unsworth, 2005). Three trials were presented for each set size (set sizes 2–5) (Unsworth, 2005), with the set size order varying randomly, so that the number of items could not be predicted by the participants (Unsworth, 2005). At recall, the participants are told in the proper order to write the words from the current set (Unsworth, 2005). In addition, a 85 percent accuracy standard assessment on math operations was demanded for all participants to ensure that they did not trade off between solving the operations and recalling the vocabularies (Unsworth, 2005). Three sets (of set size 2) of practice are offered to the participants (Unsworth, 2005). The participators are awarded for all span measurements if they were accurate and in the right position (Unsworth, 2005). The score was therefore in the correct position the total number of correct items (Unsworth, 2005).

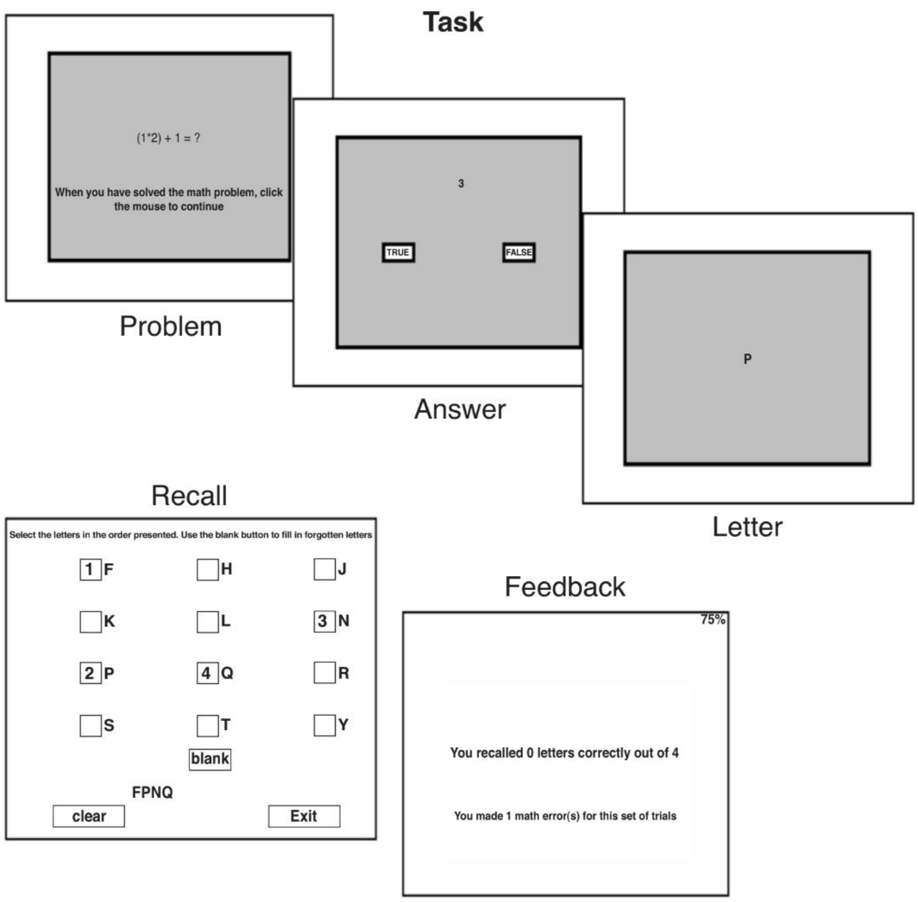


**Figure 8.** Illustration of the task of automated span operation (Unsworth, 2005). A math process is introduced first in the project(Unsworth, 2005). Participants click the mouse after it has been resolved and a digit is presented, which is considered to be either the correct or incorrect response to the math operation (Unsworth, 2005). This is accompanied by a letter for 800 msec (Unsworth, 2005). For recall, in the correct order, the right letters from the current set are chosen (Unsworth, 2005). Feedback will be presented for 2,000 msec after the recall (Unsworth, 2005).

#### 2.1.5.2 Automated O-SPAN

The Ospan model made it possible for the participants to complete the task independently of the experimenter (Unsworth, 2005). The whole task was driven by the mouse and the participator was expected to press the mouse button only (Unsworth, 2005). For this mission, the practice session was split into three parts (Unsworth, 2005). The first portion of study was a basic letter span. A letter appeared on the screen and in the same order in which they were displayed, the participants were expected to recall the letters (Unsworth, 2005). Letters appeared on-screen for 800 msec under all experimental conditions (Unsworth, 2005). The participants saw a 4-3 letter matrix (F, H, J, K, L, N, P, Q, R, S, T, and Y) in memory (Unsworth, 2005). Letters were used because previous research indicated that some of the common variation between language-using interval tasks and a higher-order cognitive metric, such as reading comprehension, was due to word knowledge (e.g., Engle, Nations, & Cantor, 1990, as cited in Unsworth, 2005). Recall consisted of clicking the box next to the corresponse letters in the correct order (no verbal answer was required) (Unsworth, 2005). The process of the recall was untimed (Unsworth, 2005). The computer provided feedback on the number of letters recovered correctly in the current set after the recall (Unsworth, 2005). The participants then practiced the task's math portion (Unsworth, 2005). Then they saw a calculation (e.g., (1* 2) 1?). Participants are told to solve the calculation as soon as possible and then click on the mouse to progress to the next screen (Unsworth, 2005). A digit (e.g., 3) was shown on the next screen and participants were asked to either press a "true" or "false" box, based on their answer (Unsworth, 2005). The participants received reliability feedback after each operation (Unsworth, 2005). The math practice helped to familiarize them with the math portion of the challenge and to determine how long that person would take to solve the math operations (Unsworth, 2005). Therefore, the science of mathematics tried to account for individual differences in the time needed to solve math operations (Unsworth, 2005). The software measured the mean time taken by each person to solve the equations after the math practice (Unsworth, 2005). This time (plus 2.5 SD) was then used for that person as a time limit for the math portion of the experimental session (Unsworth, 2005). In this practice session, the participants finished 15 mathematical operations (Unsworth, 2005).

The participants conducted both the recall letter and math parts together in the final practice session, just as they would do in the real trial frame (Unsworth, 2005). The students first saw the math task, as in the Turner then Engle Ospan, and after pressing the mouse button showing they had solved it, they saw the letter to be recalled (Unsworth, 2005). If the participants took more time than their average time plus 2.5 SD to solve the math operations, the program went on automatically and counted it as an error (Unsworth, 2005). This served to prevent the participants from rehearsing the letters when the operations were to be solved

(Unsworth, 2005). Extensive piloting was the basis for the 2.5-SD limit (Unsworth, 2005). Three practice trials of fixed size 2 are performed by the students. After all the practice sessions had been completed by the students, the program proceeded to the real trials, which consisted of three sets of each sample length, ranged from 3 to 7 (Unsworth, 2005). This made 75 letters and 75 math issues in total. Remember that for each student, the fixed size order was random (Unsworth, 2005). Set sizes ranging from 3 to 7 were used as pilot studies showed that these set sizes produced the best scoring distribution (i.e. neither on the ceiling nor on the floor) (Unsworth, 2005). There is an accuracy requirement of 85 percent for all participants (Unsworth, 2005). They were therefore encouraged to maintain their math accuracy at all times at or above 85 percent (Unsworth, 2005). In the upper right-hand corner of the screen, a percentage in red was displayed during the recall, indicating the percentage of properly solved math operations (Unsworth, 2005). The program reported five scores to the experimenter at the end of the task: Ospan score, total number correct, math errors, speed errors, and accuracy errors. Our conventional absolute scoring method was used by the first, Ospan score (Unsworth, 2005). This was the sum of all sets that were perfectly remembered (Unsworth, 2005). For example, if a person correctly remembered 3 letters in a set size of 3, 4 letters in a set size of 4, and 3 letters in a set size of 5, their Ospan rating would be 7 (3 4 0) (Unsworth, 2005). The second score, "total number correct," was in the correct position the total number of letters remembered (Unsworth, 2005). Three types of errors were reported: "math errors" were the total number of mission errors, which were then broken down into "speed errors," in which the participant was running out of time trying to resolve a given math procedure, and "accuracy errors," in which the participant incorrectly solved the math operation (Unsworth, 2005). It took about 20–25 minutes to complete the task (Unsworth, 2005).

## 2.2 Meditation

### 2.3.1 Introduction

#### 2.3.1.1 Meditation and buddism

Through Buddhist meditation and theory, mindfulness (Pali sati, Skt smUti) plays an important role (Kuan, 2007). Most contemporary Buddhist teachers are proponents of conscientiousness, particularly those pursuing the legacy of Theravada (Kuan, 2007). Mindfulness is a function or quality of mind, but it is often described as practicing or cultivating thing (Kuan, 2007). Right awareness is one of the Noble Eightfold Path components that leads to the ultimate goal of religion (Kuan, 2007). One text also notes that the honorable direction has been followed by those who have pursued the four conscientiousness institutions. Mindfulness (sati) can therefore be considered a practice (Kuan, 2007).

There are a number of forest centers in Sri Lanka that do not practice insight meditation exclusively (Kuan, 2007), although there are certainly influences from Burma there (Kuan, 2007). Most of these are possibly from an earlier stage in the Burmese wisdom tradition's development (Kuan, 2007). Some of these centers in particular teach color therapy and the characteristics of the four elements (Kuan, 2007). However, this tradition may be a relatively recent development, partly based on the texts (Kuan, 2007). There are two activities that are common among individual monks: the creation of love-kindness (to oneself and generally to all sentient beings) and the knowledge of breathing in and out (Kuan, 2007). The first of these is primarily a form of samatha or relaxed meditation, although using it in combination with insight meditation or as a calming complement to other approaches is not uncommon (Kuan, 2007). It can also be taken as the main form of meditation. As for the second, there are also several different techniques for communicating with the body, but breathing consciousness is crucially different from the other strategies in that it can be used to gain understanding or relaxation or both together (Kuan, 2007). All these kinds of practices, as seen in today's island, seem to be partly human inventions from the literature and partly something conveyed through the network of individual relations within the Buddhist sa bewilderment (Kuan, 2007). Of course, it is impossible to evaluate how old that network's meditative traditions may be, but it certainly includes ideas and practices from both Burma and Indo-China (Kuan, 2007).

#### 2.3.1.2 Meditation and psychology

The very root of East mindfulness and meditation, particularly the practice of Buddhism and Yoga within the large Indian psychological area, guides our attention to the following three big assumptions about human nature within the Indian psychology, based on Rao (2008) (Singla, 2011).

Throughout Indian psychology, the monoism of body and mind as opposed to the dualism of body and mind throughout Western psychology (Singla, 2011). The lack of dualism has direct implications for meditation practice as it means that one seeks to manipulate the mind by mindfulness, subjugate the ego, and put the physical body under the influence of the will (Singla, 2011). Likewise, awareness is also viewed as a form of mind control that is also seen in other types of traditional practices (Singla, 2011).

The second major factor is the disparity of consciousness viewpoint, which is critical when contrasting Indian psychology to Western conventional psychology (Singla, 2011). Contrary to Western psychology's biocentric bias, consciousness is the core of Indian psychology, an integral part of which is Buddhism (Rao, 2008, as cited in Singla, 2011). At the same time, it is relevant to point out that two other Indian religions, Hinduism and Jainism, along with Buddhism, share the same profound awareness of higher states of consciousness, levels of reality, and individual perfectibility (Singla, 2011). However, along with strife and competition in Indian thought, there is the fundamental truth about consciousness as the ultimate reality (Smith, 2003, as cited in Singla, 2011).

The third major hypothesis is related to the human perfectibility described above (Singla, 2011). Rao (2008) stresses that Indian psychology seeks to provide an understanding of the person's behavior, the causes and consequences of his behaviour, and to investigate ways and means of changing the individual in pursuit of perfection in being, confidence in knowledge, and satisfaction in feeling (Singla, 2011).

#### 2.3.1.3 Mindfulness and psychotherapy

‘Mindfulness' is a traditional interpretation of a word from Buddhist psychology meaning 'awareness' or 'low level of attention' (Mace, 2007). It is often used to refer to a compassionate, supportive and autonomous way of paying attention to any feelings that may be present (Mace, 2007). There are several descriptions of mindfulness: 'seeing the bare facts of life, seeing each occurrence as happening for the first time' (Goleman, 1988: p. 20); 'holding one's consciousness alive to the present reality' (Hanh, 1991: p. 11);' paying attention in a particular way: consciously, in the present moment, and non-judgmentally' (Kabat-Zinn, 1994: p. 4); 'sense of the present experience' Although it may sound very natural and casual to be conscious, it is the antithesis of mental habits in which the mind is on automatic pilot (Mace, 2007). Most interactions go through totally unrecognized in this usual state, and perception is governed by a torrent of inner opinion whose insensitivity to what is present automatically may seem senseless (Mace, 2007). Although most people experience mindfulness only for very short periods, it can be enhanced with more training (Mace, 2007).

'Mindfulness' has become a popular theme in spiritual therapy (Mace, 2007). Today, differences in how knowledge is interpreted, learned and implemented indicate that it is too early to fully evaluate its capability (Mace, 2007). The illustration of how the use of focus and knowledge in psychology reaches through conventional boundaries while counseling awareness needs more study (Mace, 2007).

Differences in how various people use mindfulness can be discerned (Mace, 2007). Some of these reflect translation hazards and others reflect long-standing ambiguities within the psychology of Buddhism (Mace, 2007). Another aspect that should not be ignored because it has ramifications for psychological practice is apparent from the way in which meditation can be used to describe self-awareness or self-awareness as well as a control of what is happening immediately (Mace, 2007). Within mainstream Buddhist conceptions of mindfulness there is also an important element of self-recollection, apparent as knowledge of inner emotional activities such as emotions and thought processes are encouraged through intentional verbal meditation (Mace, 2007). While this kind of internal commentary and its emphasis on a central 'I' is not at the heart of modern conceptions, it helps to understand how mindfulness is sometimes confused with the concept of mentalization (Mace, 2007). As a cognitive ability that is neatly considered as 'mind-mindedness' or the ability to discern entire mental states in others, mentalization remains different from any of these definitions of cognition because of the' pre-reflexive' nature of the latter (Mace, 2007).

Different ways of incorporating awareness within psychotherapy have emerged over the past two decades within the cognitive–behavioral tradition (Mace, 2007). Cognitive psychology and Buddhist psychology broadly agree on the reliance on common forms of thought and interpretation of emotional disturbance (Mace, 2007). Unlike most psychodynamic therapies, recent cognitive behavioral treatments tend to be designed as interventions for individuals with a specific set of clinical needs or disorder rather than wide-ranging therapies (Mace, 2007). Those priorities influenced the development of a flood of new approaches focused on mindfulness (Mace, 2007).

#### 2.3.1.4 Techniques for mindfulness

Many people develop mindfulness because it can be fostered by activities such as playing a musical instrument daily (Mace, 2007). However, a mixture of guided instruction and personal practice is usually learned (Mace, 2007). Typically used strategies can be classified into those that involve times of isolation from other tasks to conduct prolonged exercises (formal practices) and those that can be conducted throughout the day, in the middle of other activities (informal practices) (Mace, 2007).

Here are some techniques for experiencing mindfulness.

Formal practices: 1) Meditation when sitting (attending breathing, human sensations, vibrations, thinking, etc); 2) Meditations of movements (walking exercise, poses of yoga); 3) Team sharing (managed workouts, controlled feedback discussion (Mace, 2007).

Informal practices: 1) Mindful activity (mindful eating, cleaning, driving, etc); 2) Structured (self-monitoring, problem-solving, etc) exercises; 3) Mindful reading (particularly poetry); 4) Mini-meditations (e.g. '3 minutes' breathing) (Mace, 2007).

### 2.3.4 Effects of Meditation

#### 2.3.4.1 Meditation and the brain

Meditative and contemplative exercises include multiple co-ordinated cognitive functions that are performed concurrently, often over an extended period of time or regularly (Kelly, 2008). There is increasing evidence that meditation has significant effects on brain physiology; these effects include increased blood flow during meditation in the prefrontal cortex, lower parietal lobes and lower frontal lobes (Kelly, 2008). Furthermore, long-term meditators not only self-induce high-amplitude electroencephalographic gamma-band oscillations and phase-synchrony during meditation, but also have a higher ratio of gamma-band activity (25-42 hertz) to slow oscillatory activity (4-13 hertz) over front-parietal medial electrodes when not meditating (Kelly, 2008).

These findings suggest that prolonged or long-term meditation may have sustained effects on the brain effects physiology that persist even when the individual no longer meditates (Kelly, 2008). Meditation also has substantial, sustained effects on people who are not long-term meditators, but who engage in short-term practice (Kelly, 2008). Individuals who are not regular meditators but attend an eight-week meditation consciousness training program show significant increases in left-sided anterior activation and antibody title increases to influenza vaccine eight weeks after the end of the training; the magnitude of the increase in left-sided anterior activation predicts the magnitude of the vaccine's antibody titre increase (Kelly, 2008).

Any model that integrates these and other research findings into a single, unified theory of how meditation affects the brain is hampered by the small number of subjects in existing studies, the diversity of physiological measures examined, and general limitations on current brain structure and function understandings (Kelly, 2008). Nonetheless, An integrated model integrating neuroscientific observations with the mental and experiential correlates of meditative practice is provided, especially from the Buddhist Zen (or Ch'an) tradition. While the model is both insightful and provocative, more basic neuroscientific research and psychological investigation of the effects of meditation is clearly needed (Kelly, 2008).

#### 2.3.4.2 Neural mechanisms of mindfulness meditation

Cultivation of mindfulness, the nonjudgmental awareness of experiences in the present moment, produces beneficial effects on well-being and ameliorates psychiatric and stress-related symptoms (Kelly, 2008). Mindfulness meditation has therefore increasingly been incorporated into psychotherapeutic interventions (Kelly, 2008). Although the number of publications in the field has sharply increased over the last two decades, there is a paucity of theoretical reviews that integrate the existing literature into a comprehensive theoretical framework. There are several components through which mindfulness meditation exerts its effects: (a) attention regulation, (b) body awareness, (c) emotion regulation (including reappraisal and exposure, extinction, and reconsolidation), and (d) change in perspective on the self (Kelly, 2008). Empirical research, including practitioners' self-reports and experimental data, provides evidence supporting these mechanisms (Kelly, 2008). Functional and structural neuroimaging studies have begun to explore the neuroscientific processes underlying these components (Kelly, 2008). Evidence suggests that mindfulness practice is associated with neuroplastic changes in the anterior cingulate cortex, insula, temporo-parietal junction, fronto-limbic network, and default mode network structures. It is suggest that the mechanisms described here work synergistically, establishing a process of enhanced self-regulation (Kelly, 2008). Differentiating between these components seems useful to guide research and to specifically target areas of development in the treatment of psychological disorders (Kelly, 2008).

### 2.3.4.3 Meditation and working memory

Quach, Mano & Alexander (2016) used randomized controlled trials to examine the effect of mindfulness meditation on working memory capacity in adolescents. Participants (N= 198 teenagers) was recruited from a large public middle school in the southwest of the U.S. and randomly assigned to mindfulness, hatha yoga, or a state of waitlist regulation (Quach, 2016). Participants performed a computerized assessment of WMC (Automated Operational Period Task) and perceived pressure (Perceived Pressure Scale) and depression (Screen for Childhood Depression Related Emotional Disorders) pre-intervention and post-intervention / waitlist self-report assessments (Quach, 2016). A sequence of mixed-design variance tests was used to analyze improvements in WMC, stress, and pre-intervention and post-intervention anxiety (Quach, 2016). The results showed that participants in the relaxation state of mindfulness showed significant changes in WMC, while those in the control groups of hatha yoga and waitlist did not (Quach, 2016). Most broadly, carefulness approaches can be presented in a shorter fashion, thus increasing their ability for inclusion into school settings and current treatment protocols (Quach, 2016).

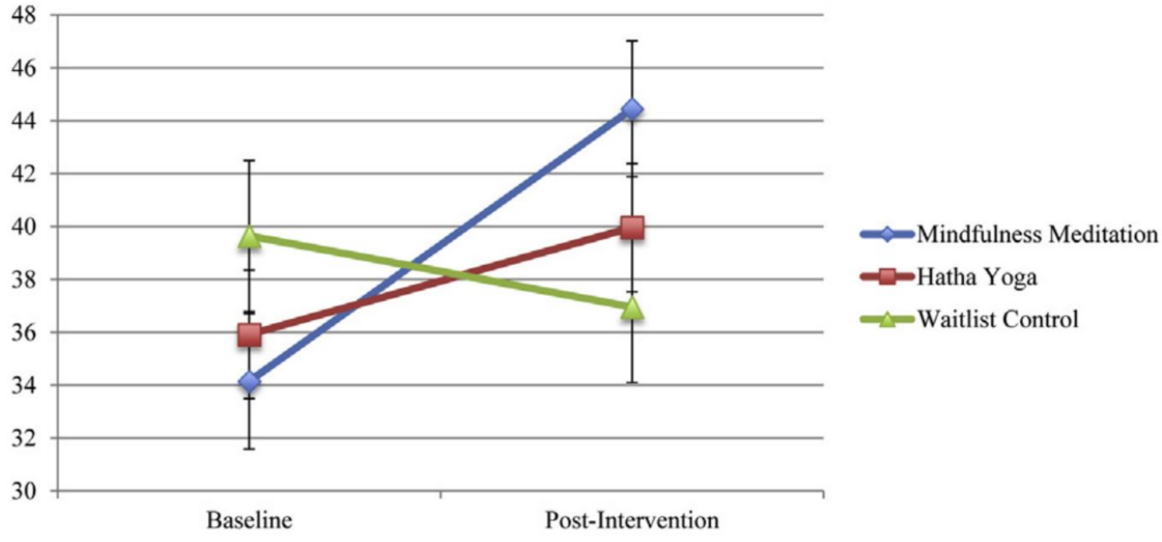


**Figure 9.** Increases in group-by-group working memory (mindfulness therapy, hatha yoga, waitlist control) from baseline to post-intervention. Error bars are a norm above and below the mean error (Quach, 2016).

### 2.3.4.4 Meditation and mental illness

There is a growing interest in exploring the potential role of meditative practices (mindfulness) in treating specific mental illnesses such as anxiety disorders, addiction, alcohol abuse, substance abuse, post-traumatic stress disorder, and psychosomatic disorders (Kelly, 2008).

Anxiety disorders are the most widely researched disorders in this setting, with a small number of studies exploring the effects of relaxation in mindfulness, anxiety control dependent on meditation, and transcendental meditation (Kelly, 2008). Nonetheless, a study of the Cochrane Collaboration revealed a notable lack of high-quality, randomized controlled meditation treatment trials for anxiety disorders, with only two findings qualifying for inclusion (Kelly, 2008). However, the researchers noted that drop-out levels were high; no adverse effects of meditation had been reported; and further research was required before conclusions could be made (Kelly, 2008).

IZuroff and Schwartz (1978) used transcendental meditation for university students who did not have any kind of prior meditation practice (Beauchemin, 2008). To distinguish the influence of behavioral and physiological causes, patients are assigned to a category of sleep, a group of muscle relaxation, or a control group of non-treatment, each lasting 9 weeks (Beauchemin, 2008). Unlike Smith (1976), the results showed reductions in self-report measurements of trait anxiety among meditation group participants (state anxiety was not evaluated) (Beauchemin, 2008). Zuroff and Schwartz concluded that a true therapy outcome is associated with the gradual reduction in depression found for the meditation group (Beauchemin, 2008).

DeBerry et al. (1989) conducted a 10-week experiment using 32 participants, aged between 65 and 75, complaining of anxiety, nervousness, tension, insomnia, and depression in a related vein (Beauchemin, 2008). The meditation group showed a significant decrease in state anxiety when compared to a cognitive therapy group and a pseudo therapy control group (where participants were only offered information about anxiety and opportunities to discuss anxiety), but no significant therapy effect was observed for trait anxiety (Beauchemin, 2008). The authors concluded that "by creating a fun mental state, it is easier to reduce depression on a short-term basis than to change a system of values that has been maintained aggressively for years" (p. 244) (Beauchemin, 2008).

#### 2.3.4.5 Meditation and social skills

The effect of meditation on the social skills of 230 adults (133 males, 97 females) was explored by Ganguli (1988) using a qualitative method (Beauchemin, 2008). The mindfulness practice consisted of a four-day large-group training course focused on inner imagination, supplemented by regular sessions for smaller groups concentrating on more specific topics such as pain control and artistic visualization (Beauchemin, 2008). Participants were asked to assess for themselves whether they encountered improvements in multiple dimensions, including their social and behavioral interactions based on perceived performance of their social skills (e.g. appropriate expressions of emotions, appropriateness of their verbal and nonverbal attitudes, and facets of speech such as facial expression, stance, intonation, and ges) (Beauchemin, 2008). For 100 percent of respondents, content analysis of the responses demonstrated change for interpersonal relationships, indicating a positive effect of mindfulness practice on social functioning (Beauchemin, 2008). The procedures for designing and collecting data did not permit causality inferences (Beauchemin, 2008).

Currently, it must be seen as tentative to assert that meditation strongly influences social skills, although plausible (Beauchemin, 2008).

## 2.3 Yoga

### 2.3.1 History and Introduction

#### 2.3.1.1 History

The concept of Yoga was originated from the Sanskrit word yuj, meaning "yoke," refers to the spiritual path connected with the seeker (Chryssides, 2012) . A characteristic of Indian religious traditions, it is found primarily in Hinduism, Buddhism, Jainism, and some forms of Sikhism (Chryssides, 2012) . Patanjali's Yoga Sutras (second to third centuries BCE) describes eight "limbs" in yoga for the attainment of moksha (final liberation): yama (external regulation of one's senses), niyama (command of one's mind), asana (physical postures), pranayama (control of one's breathing), pratyahara (internal control of one's senses), dhyana (concentration or contemplation), and samadhi (ultimate control of one's breathing) (Chryssides, 2012) . Hatha yoga— popularly referred to as "yoga "— combines the third and fourth steps of Patanjali and is primarily aimed at physical health (Chryssides, 2012). The ultimate goal of Yoga is moksha, but its forms are also used to attain higher levels of consciousness, regeneration, and spiritual (laya yoga) energies (Chryssides, 2012).

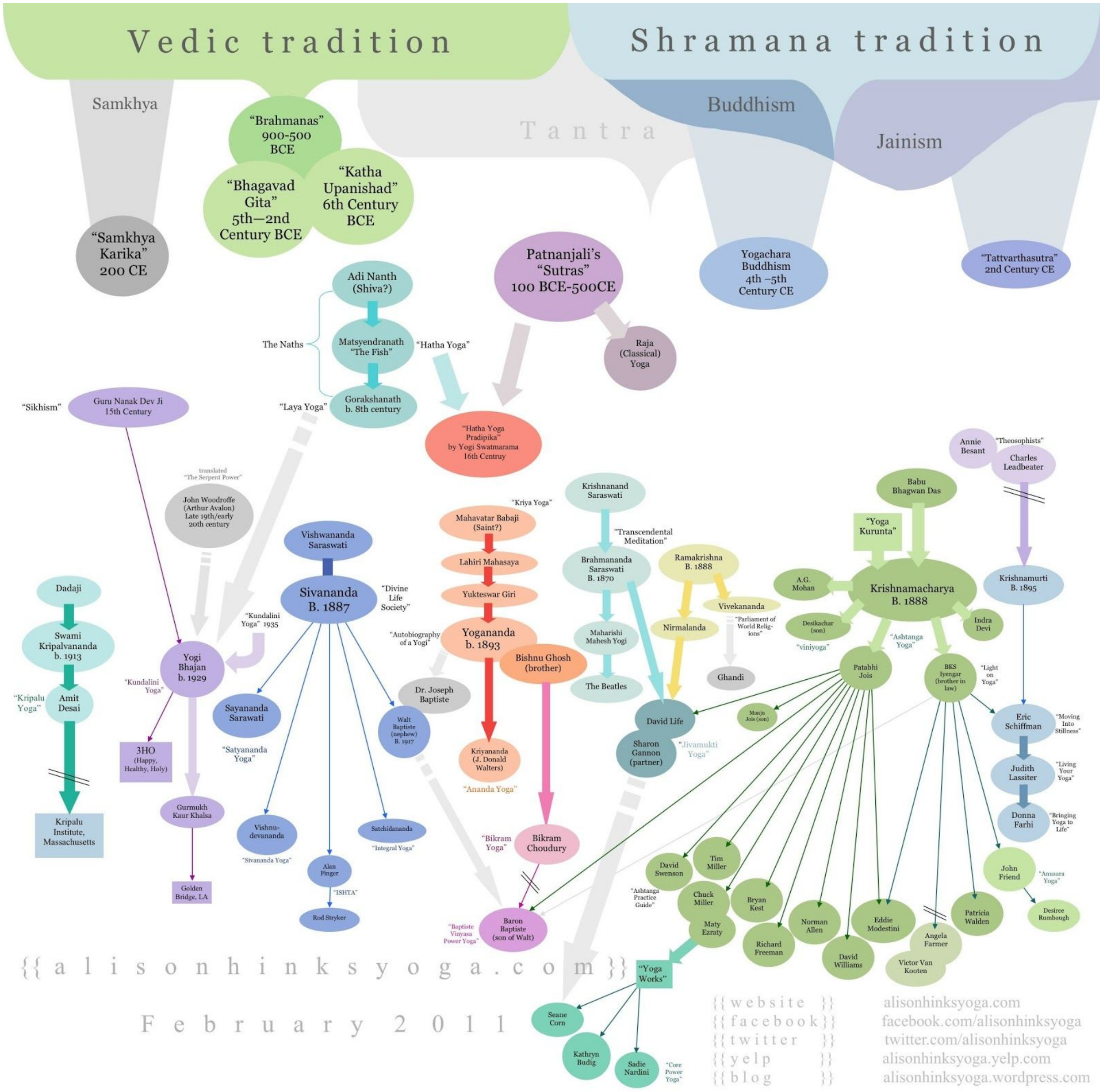


**Figure 10.** Historical development of yoga. From https://alisonhinksyoga.wordpress.com/infographics/, Copyright 2011 by alisonhinks

Because of its oral transmission of sacred texts and the secretiveness of its teachings, the history of yoga has many points of mystery and confusion (Burgin, n.d.). On delicate palm leaves, which were easily damaged, ruined or lost, the early writings on yoga were transcribed (Burgin, n.d.). Yoga creation can be traced back to more than 5,000 years ago, but some researchers believe yoga might be up to 10,000 years old (Burgin, n.d.). It is possible to split the long rich history of yoga into four major stages of growth, learning and creation (Burgin, n.d.).

Yoga's beginnings have been developed over 5,000 years ago by the Indus-Sarasvati civilization in Northern India (Burgin, n.d.). In the oldest sacred texts, the Rig Veda, the word yoga was first mentioned (Burgin, n.d.). The Vedas were a set of texts to be used by Brahmins, the Vedic priests, including poems, mantras and rituals (Burgin, n.d.). The Brahmans and Rishis (mystic seers) who recorded their practices and beliefs in the Upanishads, a vast work of over 200 scriptures, gradually mastered and established Yoga (Burgin, n.d.). The most famous of the Yogic scriptures is the Bhagavad-Gîtâ, written around 500 B.C.E (Burgin, n.d.). The Upanishads take from the Vedas the concept of ritual sacrifice and internalized it, introducing self-knowledge, practice (karma yoga) and wisdom (jnana yoga) to the sacrifice of ego (Burgin, n.d.).

In the pre-classical period, yoga was a mishmash of different ideas, values and methods that often contradicts one another (Burgin, n.d.). Patanjali's Yoga-Sûtras, the first formal introduction of yoga, describes the Classical Period (Burgin, n.d.). This text explains the direction of Raja Yoga, also called "classical yoga," published some time in the second century (Burgin, n.d.). Patanjali arranged yoga practice into an "eight limbed path" that included steps and steps toward achieving samadhi or enlightenment (Burgin, n.d.). Patanjali is often known as the founder of yoga, and his Yoga-Sûtras still have a strong influence on most western yoga forms (Burgin, n.d.).

Yoga masters created a system of exercises a few decades after Patanjali to rejuvenate the body and prolong life (Burgin, n.d.). We dismissed the ancient Vedas ' doctrines and accepted the physical body as the path to attain enlightenment (Burgin, n.d.). They developed Tantra Yoga to cleanse the body and mind with radical techniques to break the knots that bind us to our physical existence (Burgin, n.d.). The discovery of these physical-spiritual relations and body-centered exercises led to the creation of what we think of yoga in the West in the first place: Hatha Yoga (Burgin, n.d.).

Yoga masters started to travel to the West in the late 1800s and early 1900s, attracting attention and followers (Burgin, n.d.). It began at the Chicago Parliament of Faiths in 1893, when Swami Vivekananda wowed the attendees with his yoga teachings and the universality of the religions of the world (Burgin, n.d.). In 1924 Krishnamacharya opened Mysore's first Hatha Yoga School and in 1936 Sivananda founded the Divine Life Society on the banks of the Holy Ganges River (Burgin, n.d.). Krishnamacharya created three students to continue his tradition and boost Hatha Yoga's popularity: B.K.S. Iyengar, T.K.V. Desikachar and Pattabhi Jois (Burgin, n.d.). Sivananda was a prolific author who authored more than 200 yoga books and set up nine ashrams and several yoga centers around the world (Burgin, n.d.).

Importing yoga to the West continued at a trickle until 1947 when Indra Devi opened her Hollywood yoga studio (Burgin, n.d.). Since then, practitioners have become many more Western and Indian teachers, popularizing hatha yoga and attracting millions of followers (Burgin, n.d.). Hatha Yoga now has many different schools or forms, all showcasing the practice's many different aspects (Burgin, n.d.).

Particularly in the United States, yoga has become a luxury (White, 2012). Statistics show that every year, approximately 16 million Americans practice yoga (White, 2012). This means going to a yoga studio with yoga mats, yoga shoes, and yoga accessories for most individuals, and exercising in classes under the instruction of a yoga teacher or mentor (White, 2012). Here, yoga practice includes a regimen of postures (āsanas)—sometimes held for long periods of time, sometimes carried out in a rapid sequence— often in conjunction with breath control techniques (prānāyāma) (White, 2012). Yoga entrepreneurs have branded their own practice styles, ranging from the superheated workout rooms at Bikram to studios that have started offering "doga," practicing yoga with one's dog (White, 2012). They opened franchises, invented logos, packed their practice regimes under Sanskrit names, and marketed a lifestyle that combines yoga with recreational travel, healing spas, and eastern spirituality seminars (White, 2012). "Yoga celebrities" became part of our vocabulary, and the usual entourage of advertisers, business managers, and lawyers came with celebrity. It's mainstream yoga (White, 2012). Probably India's greatest cultural export, yoga has been turned into a phenomenon of popular culture (White, 2012).

#### 2.3.1.2 Types of yoga

There are many different types of yoga and most yoga styles are based on the same basic poses of yoga (called asanas), but one style's experience may be radically different from another (“Different Types of Yoga”, n.d.).


**Figure 11.** Hatha Yoga (Surya Namaskar). From https://www.vectorstock.com/9568498 , Copyright 2019 by Vectortstock.com

Hatha Yoga. Hatha is a general category comprising most styles of yoga ("Different Types of Yoga", n.d.). It is an old system that includes asanas (yoga postures) and pranayama (breathing exercises) practice that helps bring peace to mind and body, preparing the body for deeper spiritual practices such as meditation ("Different Types of Yoga", n.d.). The term hatha is so widely used that it's hard to know what a particular hatha is ("Different Types of Yoga", n.d.). In most cases, it will be relatively gentle and slow ("Different Types of Yoga", n.d.). (Different Types of Yoga)

Vinyasa yoga, like hatha, is a general term describing many different yoga styles ("Different Types of Yoga", n.d.). This essentially means breath-synchronized movement and is a vigorous style based on a fast stream through greetings from the wind ("Different Types of Yoga", n.d.). Vinyasa also refers to the continuous flow from one position of yoga to another ("Different Types of Yoga", n.d.).

Ashtanga yoga. Ashtanga is a yoga system brought by Sri K. Pattabhi Jois to the modern world ("Different Types of Yoga", n.d.). Through ashtanga cycle, always in the same order, is a non-stop fixed sequence of asanas ("Different Types of Yoga", n.d.). It's usually fast-paced, energetic and demanding physically (“Different Types of Yoga”, n.d.). In total, there are six series, increasing in difficulty as one moves on from the primary series (“Different Types of Yoga”, n.d.).

Power yoga. A intense, vinyasa-style yoga is used to characterize power yoga (“Different Types of Yoga”, n.d.). This initially resembled ashtanga closely and was an attempt to make ashtanga more available to students from the West (“Different Types of Yoga”, n.d.). Nevertheless, it varies in that it is not a predetermined sequence of poses, but rather gives the flexibility for practice (“Different Types of Yoga”, n.d.). Inventing power yoga is most often attributed to two American yogis, Beryl Bender Birch and Bryan Kest, both of whom trained with Sri K. Pattabhi Jois (“Different Types of Yoga”, n.d.). The influence of Power Yoga has spread throughout the world

Jivamukti yoga. In 1984, David Life and Sharon Gannon created jivamukti yoga, studying with a number of teachers since then, including Swami Nirmalananda and Sri K. Pattabhi Jois (“Different Types of Yoga”, n.d.). Their classes look like ashtanga flowing through asanas in the vinyasa-style. Each class starts with a standardized sequence of warm-ups unique to jivamukti, and teachers often incorporate weekly themes, chanting, meditation, readings, and affirmations (“Different Types of Yoga”, n.d.).

Iyengar yoga. Iyengar's trademark is the intense focus on each posture's subtleties (“Different Types of Yoga”, n.d.). B.K.S. Iyengar conducts his lessons from his home in Pune, India, and has become one of today's most popular gurus (“Different Types of Yoga”, n.d.). Poses are held much longer in a typical iyengar class than in other yoga schools in an attempt to pay more attention to the precise musculoskeletal alignment within each asana (“Different Types of Yoga”, n.d.). Another trademark of iyengar is the use of props such as blocks, belts, bolsters, chairs and blankets to accommodate injuries, tightness or structural imbalances, as well as teaching the student how to move properly into a posture (“Different Types of Yoga”, n.d.). (Different Types of Yoga)

Anusara yoga. The anusara method is a modern hatha model that teaches a series of Universal Concepts of Alignment guiding all yoga postures, while promoting grace-flowing and heart-following (“Different Types of Yoga”, n.d.). The practice of anusara, founded by John Friend, is broadly divided into three parts, known as the Three A's (“Different Types of Yoga”, n.d.). They include behavior, alignment, and action (“Different Types of Yoga”, n.d.).

Sivananda yoga. Sivananda is a hatha form founded by Swami Sivananda that Swami Vishnu-devananda brought to the west (“Different Types of Yoga”, n.d.). A class typically begins with Savasana, kapalabhati and anuloma viloma, followed by a few rounds of surya namaskara (“Different Types of Yoga”, n.d.). The practice then goes through the twelve asanas of Sivananda, which are built together to increase the spine's strength and flexibility (“Different Types of Yoga”, n.d.). Chanting and reflection can be part of a full-length course as well (“Different Types of Yoga”, n.d.). Vishnu-devananda founded the International Sivananda Yoga Vedanta Centers, summarizing the philosophy of Sivananda in five main principles: proper exercise (asanas); proper breathing (pranayama); proper relaxation (savasana); proper diet (vegetarian); and positive thinking (vedanta) and mindfulness (dhyana) (“Different Types of Yoga”, n.d.).

Viniyoga yoga. Viniyoga refers to an approach to yoga which adapts to the particular situation, desires and preferences of the student the various means and methods of study (“Different Types of Yoga”, n.d.). Designed by T.K.V. Desikachar, the goal is to provide the patient with the resources to individualize and upgrade the self-discovery and personal transformation process (“Different Types of Yoga”, n.d.).

Kundalini yoga. Kundalini combines repetitive exercises or gestures, complex methods for pacing, singing, meditation and mantras (“Different Types of Yoga”, n.d.). Each particular kundalini practice, called a kriya, is a frequently repeated movement that is associated with air (“Different Types of Yoga”, n.d.). The practice is intended to awaken the energy at the base of the spine and bring it up through each of the seven chakras (“Different Types of Yoga”, n.d.). Brought by Yogi Bhajan to the west, this type of yoga looks and feels very different from any other, due to its emphasis on regular, intensified breathing and energy transfer through the body (“Different Types of Yoga”, n.d.).

Yin yoga. Yin yoga is a slow-paced style that keeps poses for five or more minutes (“Different Types of Yoga”, n.d.). Even if it is relaxed, because of the long holds, yoga can be quite difficult, particularly if the body is not used to it (“Different Types of Yoga”, n.d.). The purpose is to apply moderate stress to the connective tissue— the tendons, fascia and ligaments— in order to increase joint circulation and improve flexibility (“Different Types of Yoga”, n.d.). It was developed by martial arts expert and taoist Paulie Zink and was first practiced in the U.S. in the late 1970s ("Different Types of Yoga", n.d.). Yin-style is now being practiced in North America and Europe, largely due to two of the most influential educators, Paul Grilley and Sarah Powers ("Different Types of Yoga", n.d.).

Integrative yoga. Integrative yoga practice incorporates asanas, pranayama, mudra, yoga nidra, mantra, and mindfulness into a complete package that can be used for rehabilitation ("Different Types of Yoga", n.d.). Founded in 1993 by Joseph Le Page, IYT was an attempt to focused on yoga as a therapeutic practice, with specifically designed courses for clinical and traditional health environments, including hospitals and recovery centres ("Different Types of Yoga", n.d.).

Restorative yoga. Restorative is a gentle, relaxing, passive style that allows students to relax and release their body into a smooth stretch that lasts as long as 10 minutes ("Different Types of Yoga", n.d.). A wide range of accessories, including bolsters, frames, braces and blankets, are used in this model ("Different Types of Yoga", n.d.). Within each posture, the aim is to provide strength, making it easier to fully let go.

### 2.3.2 Effects of Yoga

#### 2.3.2.1 Yoga and brain

Practices of yoga meditation may induce a state of mindfulness that, if recurrently evoked by repeated practice, may develop into trait or dispositional awareness (Froeliger, 2012). Experience-dependent neuroplastic changes can mediate these changes. A study (Froeliger, 2012) investigated the differences in GMV between practitioners of yoga meditation (YMP) and a matched control group (CG). The YMP group reported a higher volume of GM in frontal, limbic, temporal, occipital, and cerebellar regions; while there was no greater regional GMV in the CG (Froeliger, 2012). Moreover, on the Cognitive Failures Questionnaire (CFQ), the YMP group reported significantly fewer cognitive failures, the magnitude of which was positively correlated with GMV in various regions found and GMV positively correlated with the length of yoga practice (Froeliger, 2012). The results suggest that the practice of hatha yoga may be consistent with encouraging neuroplastic improvements in executive brain systems, which can provide therapeutic benefits that accrue with regular practice (Froeliger, 2012).

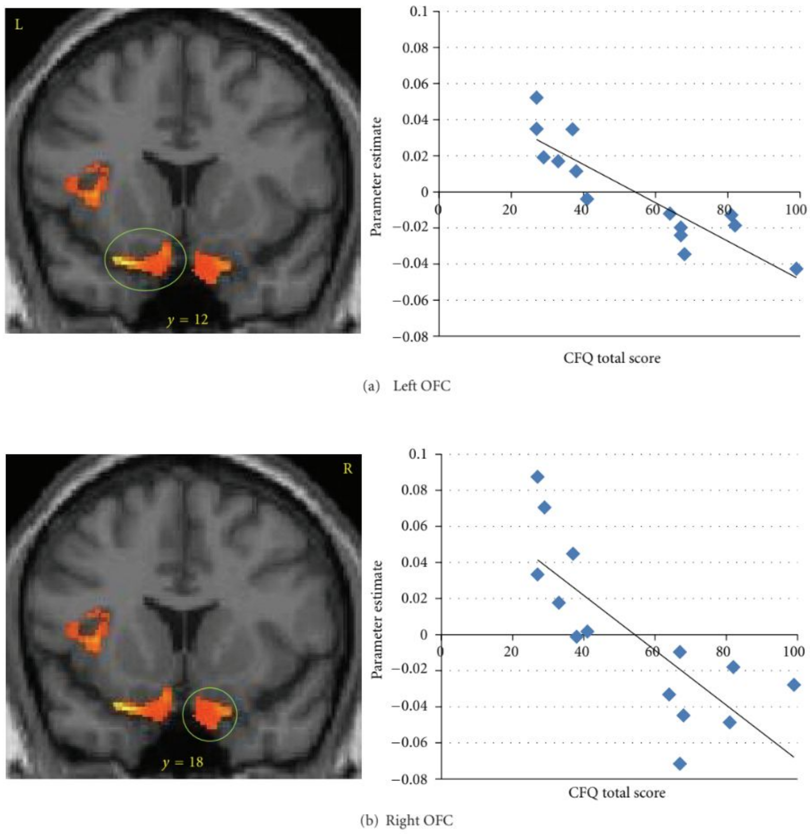


**Figure 12.** For yoga meditation participants, the volume of gray matter (GMV) was greater than in (a) left orbital frontal cortex (OFC; −22, 12, −21) and (b) right OFC (6,18, −19). A negative association between OFC GMV and self-reported cognitive failures (Froeliger, 2012).

Keeping hatha yoga practice longer may arouse the connectivity and neuroplasticity of the front cerebellar by virtue of the intensive, multimodal, cognitive and motor skill learning involved in such practice (Froeliger, 2012). Hatha yoga includes the complex training context, high variability of tasks, increasing difficulty of tasks, motivated states of excitement, and long duration of training considered necessary for process-specific learning underground with brain plasticity (Froeliger, 2012). In fact, hatha yoga practice requires exquisite executive control to coordinate body posture and breathing while keeping the focus on proprioceptive and interoceptive feedback in the face of distracting thoughts and body discomfort (Froeliger, 2012). Furthermore, the rigors of yoga need ardent motivation, which increases in difficulty as the practice deepens (Froeliger, 2012). To order to gradually transition into more demanding physical postures when coordinating the alignment of the limbs with respiration, tremendous coordination is required (Froeliger, 2012). According to these features, systematic study of yoga meditation will promote cognitive plasticity through the intensive mental training involved in this exercise (Froeliger, 2012). Practice of yoga and meditation can serve as an effective treatment intervention for disorders with concomitant atrophy of GM volume and cognitive problems (Froeliger, 2012). GM atrophy, for example, is associated with a wide range of psychiatric conditions including depression, age-related mild cognitive impairment and depression, posttraumatic stress disorder, and chronic pain (Froeliger, 2012). Furthermore, substance use disorders are associated with decreased volume of GM; including alcohol addiction, smoking, and psychostimulants (Froeliger, 2012). Importantly, GM volume decreases were observed to be consistent with cognitive function in frontal and limbic regions (Froeliger, 2012). In line with the hypothesis that yoga meditation practice can remedy psychiatric conditions, a recent review paper of over 90 studies found that mind-body therapies improved depressive symptoms in patients with a wide range of disorders (Froeliger, 2012). About addictive disorders, it was recorded that Yoga improved recovery from substance abuse disorders and improved smoking cessation outcomes in individuals dependent on nicotine (Froeliger, 2012). Future research is needed to determine whether such therapeutic benefits derive from increased mindfulness and neuroplasticity stemming from state-by-trait interactions (Froeliger, 2012).

#### 2.3.2.2 Yoga and neuro-cognitive functions

Sahaj Yoga is a type of "Kundalini Yoga," explaining a simple technique to arouse man's latent potential through a simple process of meditation (Sharma, 2006). While treating Hypertension, bronchial asthma and epilepsy, Sahaj Yoga has shown beneficial effect (Sharma, 2006). Past scientific studies on Sahaj Yoga have also shown its effectiveness in lowering levels of anxiety, enhancing sensory-motor processing, reaction time and increasing autonomous regulation in athletic practitioners (Sharma, 2006).

Studies on the cognitive function impact of Yoga have shown improvement in memory, resilience, and anxiety levels (Sharma, 2006). In Major Depression, cognitive functions are diminished (Sharma, 2006). Thirty patients with major depression (age 18 to 45 years) were randomly divided into two groups in a study (Sharma, 2005). Group 1 consists of people who have been meditating on Sahaj Yoga and have also received traditional antidepressant medication (Sharma, 2006). Group 2 is made up of patients who have taken only traditional antidepressant drugs (Sharma, 2006). Patients in Group 1 are given 8 weeks of Sahaj Yoga practice (Sharma, 2006). After 8 weeks, Group 1 and Group 2 subjects showed significant increases in neuro-cognitive tests (used to measure attention span, visuo-motor speed, short-term memory, working memory and executive functions), but progress in Group 1 subjects was more pronounced (Sharma, 2006). The results show that in addition to improvements in various other cognitive domains seen with traditional anti-depressants, Sahaj Yoga practice will lead to additional change in executive functions such as controlling information in the verbal working memory and added improvement in attention span and visuo-motor speed of the depressives (Sharma, 2006).

#### 2.3.2.3 Mindfulness-based stress reduction

MBSR is an mindfulness-based training program created by Jon Kabat-Zinn to relieve adult suffering, including mindfulness meditation and mindful Hatha yoga (Kabat-Zinn, 1990/2005, as cited in White, 2012). Mindfulness is a present-day awareness that is cultivated by purposefully paying attention to things that are not usually noticed (Kabat-Zinn, 1990/2005, as cited in White 2012). Mindfulness and yoga increases awareness of the experiences of feelings and thoughts (White, 2012). The MBSR program teaches people to recognize when the automatic stress reaction begins and to respond deliberately to prevent a hyperarousal adverse condition (Kabat-Zinn, 1990/2005, as cited in White, 2012). Adult MBSR studies indicate a decrease in pressure (Chiesa & Serretti, 2009; Grossman et al., 2004; Ospina, 2008, as cited in White, 2012), a decline in rumination and trait anxiety, and increased empathy and sympathy (Greeson, 2009, as cited in White, 2012). If asked about reciprocal and alternative therapies, teenagers show willingness to use yoga as a pain reliever (Tsao, Meldrum, Kim, Jacob, & Zeltzer, 2007, as cited in White, 2012). Evidence suggests that yoga with children can play a role in physical and psychological health (Birdee et al., 2009, as cited in White, 2012) and is associated with improved cardiovascular status, physical function and behavior (Galantino et al., 2008, as cited in White, 2012). Results studied with children and adolescents included reduced feelings of helplessness (Stueck & Gloeckner, 2005, as cited in White, 2012), improved lung function (Jain et al., 1991; Mandanmohan, Udupa, & Bhavanani, 2003, as cited in White, 2012), decreased symptoms of disease (Jain et al., 1991; Kuttner et al., 2006; Mandanmohan et al., 2003, as cited in White, 2012), and improved cognitive function (Manjunath & Telles, 2001, 2004, as cited in White, 2012).

## 3. Methodology

### 3.1 Plan and Procedure

In this study, the original plan was to have three groups of voluntary WPI undergraduate students: the control group, meditation group and yoga group. Each group has at least 5 students. The control group will take the cognitive test first (an O-SPAN test or AX-CPT test, which is about 20 minutes each), followed by the meditation and yoga group. The meditation group and yoga group will take 20 minutes and 40 minutes for their exercise before the cognitive test respectively. Theoretically each session of the experiment would take around 1 hour, there will be 5 sessions on each week in the morning and the total length of experimental study will take 4-5 weeks. The experiment is fully anonymous and completely voluntary, the system used aliases for each student to keep track of their test performance. In the report the aliases is scrambled again such that no personal information will be leaked. The participants holds the right to quit anytime when they feel necessary.

However, when it comes to execution, several unexpected factors have changed the original plan: there were only 6 volunteers recruited, making it impossible to draw and statistically meaningful conclusion even if the rest of the experiment was successful: according to the plan, there will be only 2 people in each group, a sample too small for any valid behavioral observation. To counter that the plan was changed and only two groups were proposed: the 40-minute yoga group and the 20-minute meditation group. The original control group was then ‘transferred’ to the meditators: the meditation group were asked to do the cognitive ability tests (5-20 minutes) before and after the tests. The yoga group remain unchanged. Each group has three people, although insufficient in every aspect, it was still anticipated that certain effects of enhanced cognitive ability will be observed.

The introduction section - to introduce the background, the idea behind and explain the aim of the experiment was relatively successful as all volunteers fully understood and gave their consent to contribute for the study. The yoga group managed to acquire all necessary 10 poses in the first two sessions and the meditation team seemed to be focused and comfortable at doing meditation. The initial tests were completed smoothly as expected - the volunteers were specifically told not to use any memory techniques in the working memory test and to reflect the true capacity of their brains.

However, the experiment seriously underestimated the life stress and workload or lack of will among college students. From the second week only two or three person would arrive to continue the experiment and that number decreased to one to two in the third and fourth week. All the meditation team withdrawal after merely three days. Beyond the proposed 4-week session, the fifth week is set to be the make up session, unsurprisingly, this proved to be futile for collecting more data.

Due to the problematic execution, the experiment was incomplete and therefore the research is confined to explore and interpreting the very limited existing findings.

### 3.2 Meditation Methods

The meditation methods adopted at first was the typical mindfulness yoga meditation techniques: the Pranayama (the control of the breath) - one of the eight limbs. This technique include breathing skills -alternate nostril breathing, exhale and inhale in a particular way and mindfulness meditation. During execution the techniques were not strictly followed, instead the participants preferred simpler mindfulness meditation techniques: sit and cross the legs, focus on breathing without feeling forced to control the random ideas in the mind. The total length for meditation was around 20 minutes for each session.

### 3.3 Yoga Methods

The yoga group was lead by Advisor of this Project at the beginning and later practice independently. The total length was set to 40 minutes and then reduced to 20 minutes for some reason. Participants practice 8 yoga poses during a 20 minute period, then repeat the period if possible (due to timing issue, this was cancelled). The 10 poses include: 1) Folding hands at the chest; 2) Half dancer pose (the difficulty is reduced); 3) Tree pose; 4) Eagle pose; 5) Warrior pose; 6) Triangle pose (the difficulty is reduced); 7) 90 degree hand twist; 8) T shape pose; 9) Y shape pose; 10) Folding hands at the chest (again).

### 3.4 AX-CPT and O-SPAN

The AX-CPT test is reduced to less than 20 minutes (the program has a flexible 10 minute increment), from which mind-wandering is not expected to happen or required to report. The probabilities of different pairs are: AX, 30%; AY, 20%; BX, 20%; BY, 20%; Ang 5%; Bng 5%.

The (automated) O-SPAN test is set to around 5 minutes (since there is no significant meaning for longer tests), the total O-SPAN absolute score is 30. The max length of letter sequence required to memorize is 6.

## 4. Results

Due to the lack of volunteers (only 6 person for a minimal requirement of 15 participants), most statistical methods such as the student's t test is unfit for the experiment. Consequently, the data was processed primarily relying on linear fit and a general (although ambiguous) relation concerning the volunteer's test performance and their involvement in the experiment is revealed. In addition, to further utilized the incomplete data, we focus on individual changes as well as group effects.

As for the results of the volunteers, all the raw data are reflected in the Linear fitting pictures. For the protection of privacy, the volunteers discussed are using randomized anonymous callsigns: Y_A, Y_B, Y_C for yoga group and CM_A, CM_B and CM_C for the control/meditation group.

### 4.1 AX-CPT Results

The AX-CPT test results consist of the correct rates of processing with AX, AY, BX and BY pairs and the response time between the probe and the cue for each of the types of questions. All the data are shown in the figures and a linear fit is used to evaluate a general relation between practices of yoga and meditation and test performance.

### 4.1.1 The Correct Rate

The correct rate of AX pair, AY pair, BX pair and BY pair are shown below, for each participant respectively. The Weighted total (Correct rate in average) is the sum of the correct rate of each pair times its probability, then divided by the total probability of the 4 pairs. This excludes pairs that containing numbers, when the participant is not required to response (and not response time is available). In this particular test, the total probability of the 4 pairs are 90%.

#### 4.1.1.1 Correct rate of Y_A

The data from Y_A is the most complete among all the volunteers, all the sessions were completed - there were 10 trials and results for AX-CPT as well as O-SPAN. As for the correct rate here, the result is a bit counterintuitive as there is a slight negative relation between times of trials and AX-CPT correct rate, especially for AX pairs, where the slope is -0.0054 and the R-square is 0.46667. The overall effects are also negative. However this is not very convincing as the slope is very small in absolute value and a controlled group for excluding other factors is needed for any convincing conclusion.

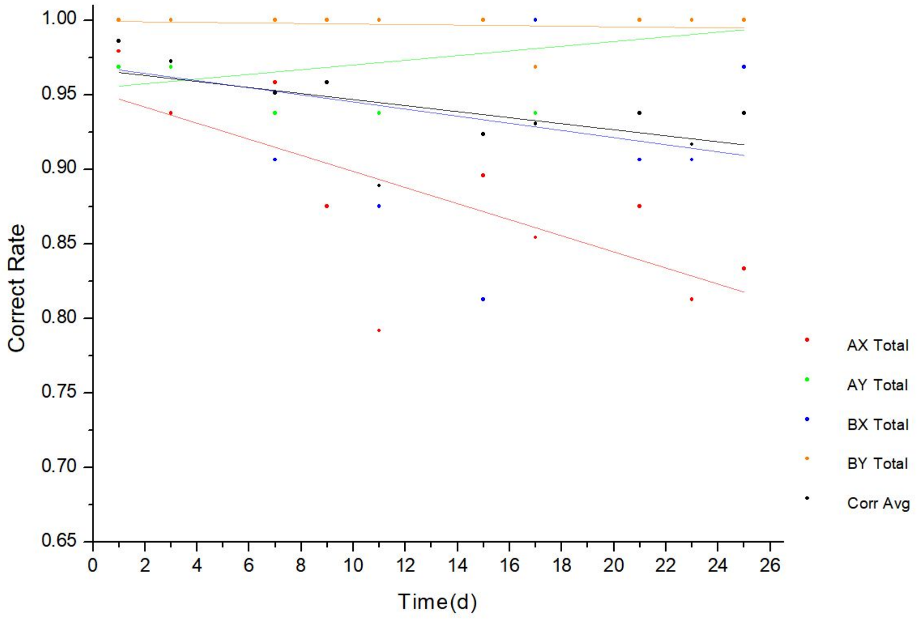


**Figure 13.** The correct rate of pairs for Y_A

| AXCPT Corr | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX total | -0.0054 | 0.00181 | 0.46667 |
| AY total | -0.00202 | 9.56026E-4 | 0.27863 |
| BX total | 0.00157 | 0.00108 | 0.11052 |
| BY total | -1.89213E-4 | 4.13011E-4 | -0.09624 |
| Weighed total | -0.00239 | 0.00266 | -0.02175 |

**Table 1.** The linear fit of correct rate of pairs for Y_A

#### 4.1.1.2 Correct rate of Y_B

Y_B have 6 AX-CPT trails and there is not clear evidence that the overall correction rate is changing. However, The AY and BX correct rates clearly positive related to yoga trials and AX correct rate is even more negatively related to yoga (the R-Square is 0.54113).

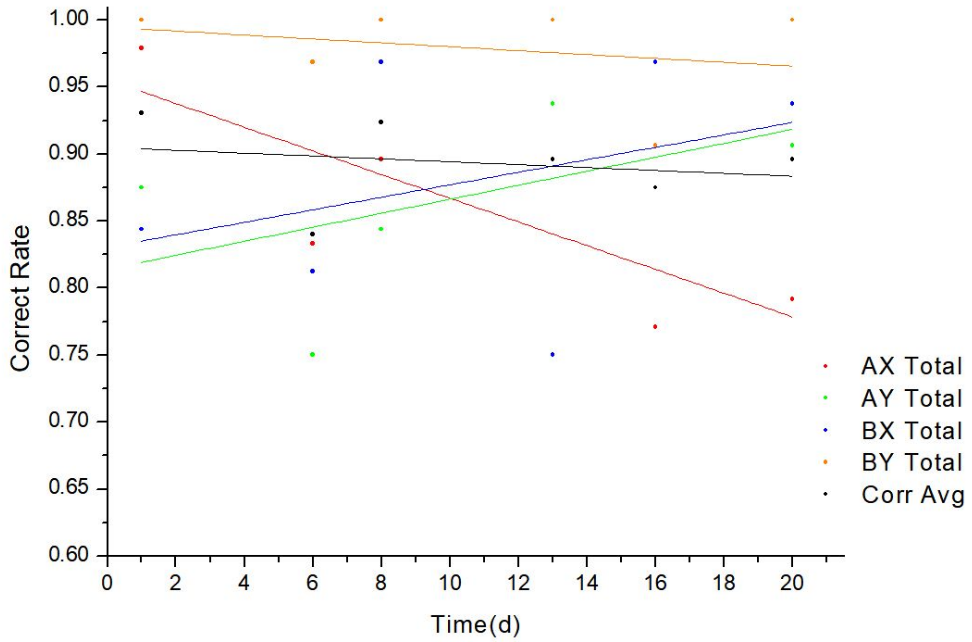


**Figure 14.** The correct rate of pairs for Y_B

| AXCPT Corr | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX total | -0.00885 | 0.00337 | 0.54113 |
| AY total | 0.00522 | 0.00401 | 0.00401 |
| BX total | 0.00467 | 0.00613 | -0.09168 |
| BY total | -0.00146 | 0.00261 | -0.16002 |
| Weighed total | -0.00107 | 0.00231 | -0.18569 |

**Table 2**. The linear fit of correct rate of pairs for Y_B

#### 4.1.1.3 Correct rate of Y_C

There are only three AX-CPT trails for Y_C, the correct rates are in general slightly positive related to the total yoga practice, especially for the AX pair (the slope is 0.003).

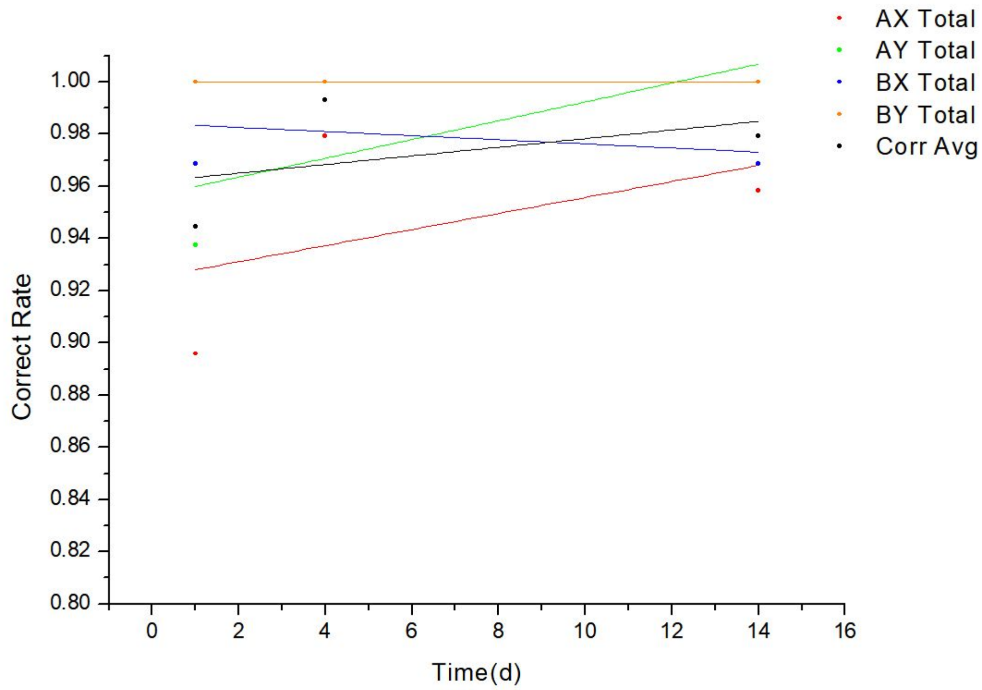


**Figure 15.** The correct rate of pairs for Y_C

| AXCPT Corr | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX total | 0.00307 | 0.00558 | -0.53486 |
| AY total | 0.0036 | 0.00389 | -0.07914 |
| BX total | -0.00157 | 0.00108 | 0.11052 |
| BY total | 0 | 0 | - |
| Weighed total | 0.00165 | 0.00329 | -0.59823 |

**Table 3.** The linear fit of correct rate of pairs for Y_C

#### 4.1.1.4 Correct rate of CM_A

There are only 2 trials of AX-CPT for CM_A and these two trials are taken together with a 20 minutes meditation. Although lacking data, this is still a illustration of short time effects of meditation on cognitive ability. The effect is slightly negative in this case (Weighted total slope is -0.001).

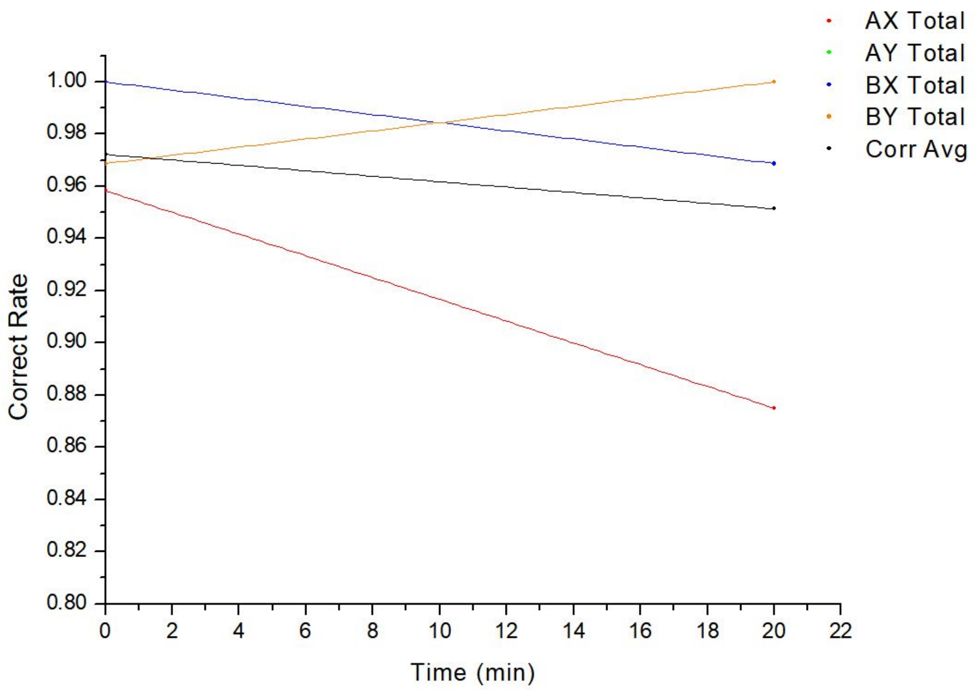


**Figure 16.** The correct rate of pairs for CM_A

| AXCPT Corr | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX total | -0.00417 | - | - |
| AY total | 0.00156 | - | - |
| BX total | -0.00156 | - | - |
| BY total | 0.00156 | - | - |
| Weighed total | -0.00104 | - | - |

**Table 4.** The linear fit of correct rate of pairs for CM_A

#### 4.1.1.5 Correct rate of CM_B

Similar to CM_A, there are only 2 trials of AX-CPT for CM_B and these two trials are taken together with a 20 minutes meditation. This is still a illustration of short time effects of meditation on cognitive ability. The effect is slightly positive in this case (Weighted total slope is 0.0017).

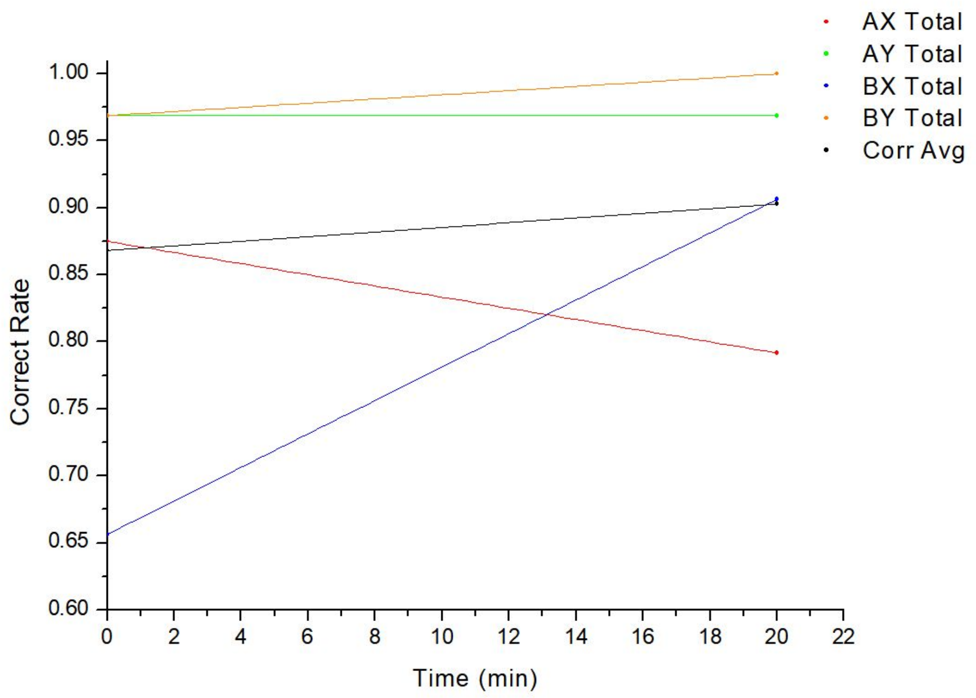


**Figure 17.** The correct rate of pairs for CM_B

| AXCPT Corr | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX total | -0.00417 | - | - |
| AY total | 0 | - | - |
| BX total | 0.0125 | - | - |
| BY total | 0.00156 | - | - |
| Weighed total | 0.00174 | - | - |

**Table 5.** The linear fit of correct rate of pairs for CM_B

### 4.1.1.6 Correct rate of CM_C

Similar to CM_A, there are only 2 trials of AX-CPT for CM_C and these two trials are taken together with a 20 minutes meditation. This is still a illustration of short time effects of meditation on cognitive ability. The effect is positive in this case (Weighted total slope is 0.0038). It is noteworthy that all the correct rate increased after meditation. (The change of weighted is 7.6%)

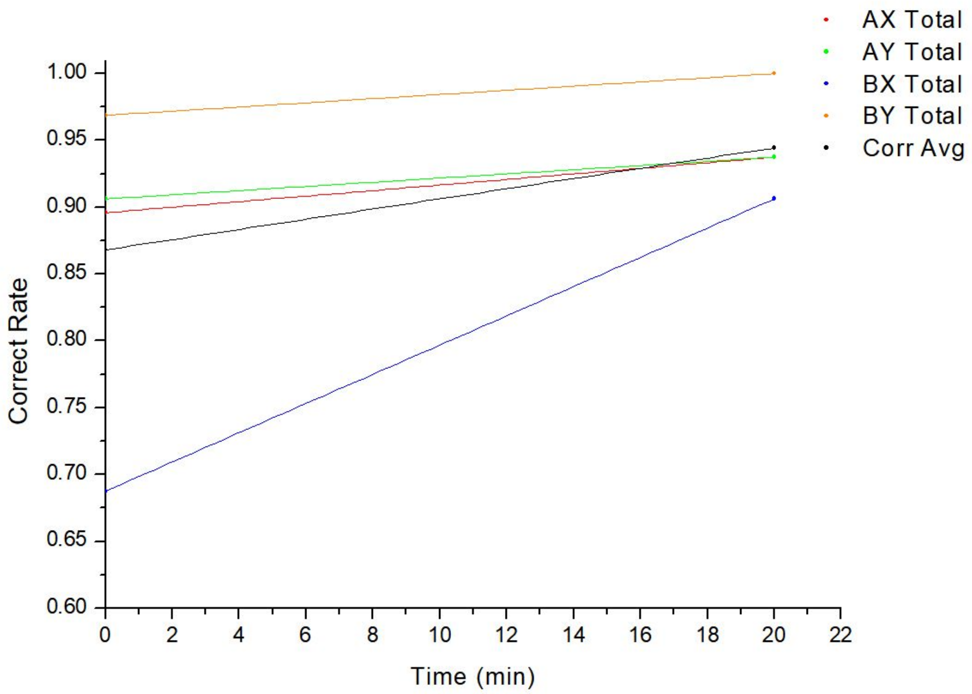


**Figure 18.** The correct rate of pairs for CM_C

| AXCPT Corr | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX total | 0.00208 | - | - |
| AY total | 0.00156 | - | - |
| BX total | 0.01094 | - | - |
| BY total | 0.00156 | - | - |
| Weighed total | 0.00382 | - | - |

**Table 6.** The linear fit of correct rate of pairs for CM_C

### 4.1.2 The Response Time

The response time of AX pair, AY pair, BX pair and BY pair are shown below, for each participant respectively. The Weighted RT (response time in average) is the sum of the mean response time of each pair times its probability, then divided by the total probability of the 4 pairs. This excludes pairs that containing numbers, when the participant is not required to response (and not response time is available). In this particular test, the total probability of the 4 pairs are 90%.

#### 4.1.2.1 Response time of Y_A

The response times of Y_A is stable in general, all the slopes are very small except for BX pair.

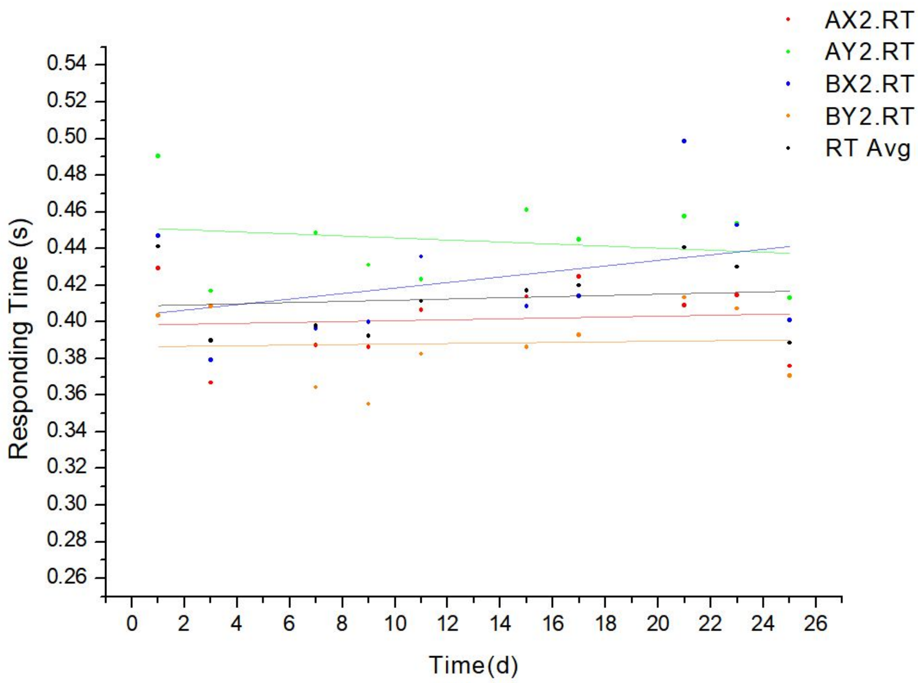


**Figure 19.** The response time of pairs for Y_A

| AXCPT RT | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX RT | 2.43874E-4 | 8.87691E-4 | -0.11449 |
| AY RT | -5.57166E-4 | 9.83193E-4 | -0.08158 |
| BX RT | 0.00151 | 0.0014 | 0.01826 |
| BY RT | 1.50667E-4 | 8.5357E-4 | -0.12064 |
| Weighed RT | 3.26384E-4 | 8.50254E-4 | -0.10465 |

**Table 7.** The linear fit of response time of pairs for Y_A

#### 4.1.2.2 Response time of Y_B

The response times of Y_B is stable in general, all the slopes are very small except for AY pair.

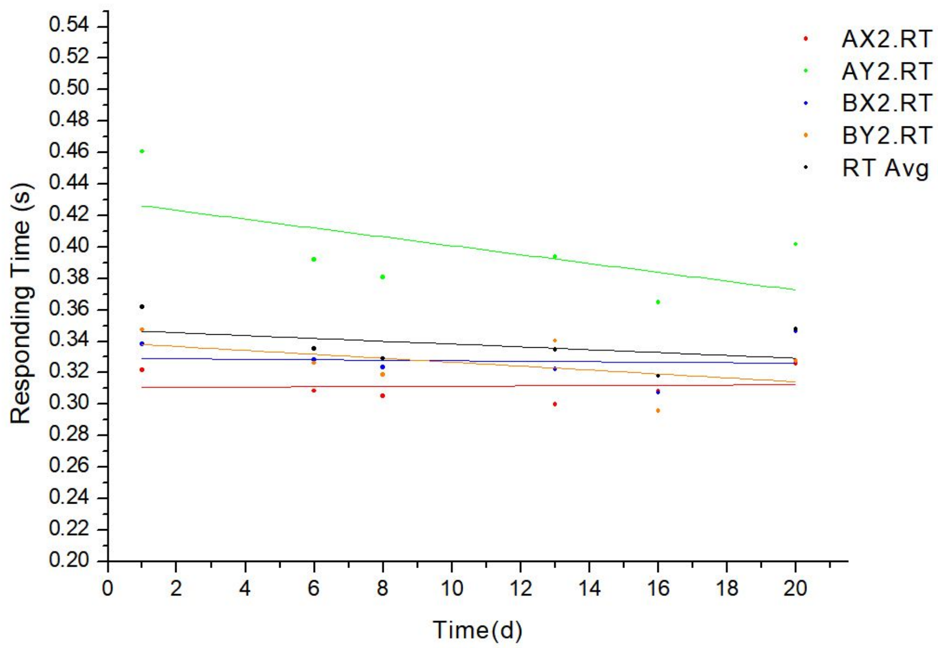


**Figure 20.** The response time of pairs for Y_B

| AXCPT RT | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX RT | 9.26876E-5 | 7.17512E-4 | -0.24481 |
| AY RT | -0.00282 | 0.00189 | 0.19603 |
| BX RT | 1.56449E-4 | 9.68334E-4 | -0.2419 |
| BY RT | -0.00125 | 0.00114 | 0.0379 |
| Weighed RT | -9.06496E-4 | 9.97887E-4 | -0.03622 |

**Table 8.** The linear fit of response time of pairs for Y_B

#### 4.1.2.3 Response time of Y_C

The response times of Y_C showed a trend of decrease with the slope for Weight RT -0.00386. The most significant drop in response times is BX pair, with a slope of -0.00849.

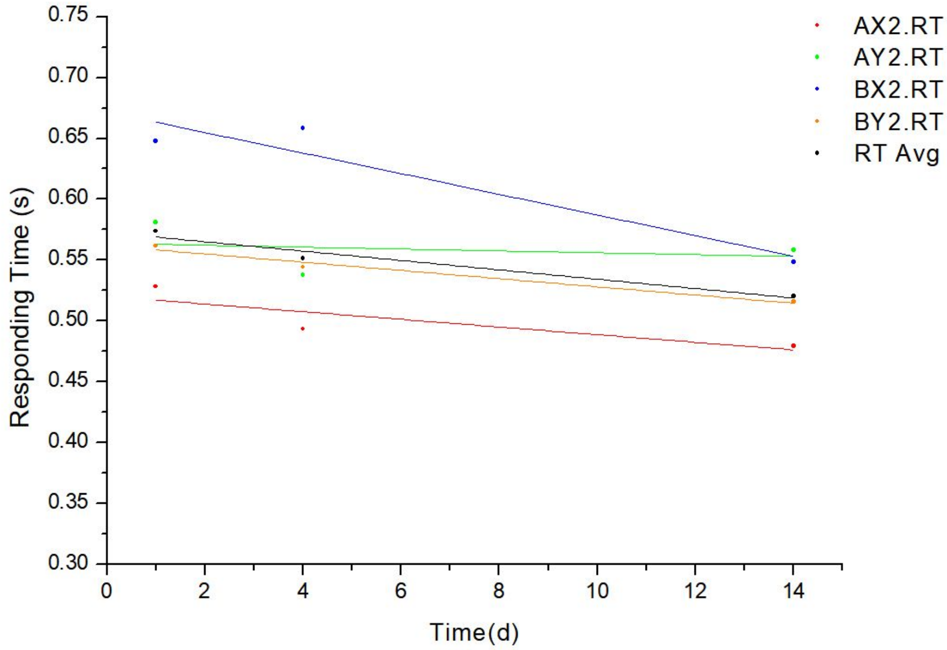


**Figure 21.** The response time of pairs for Y_C

| AXCPT RT | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX RT | -0.00315 | 0.00191 | 0.46142 |
| AY RT | -7.69593E-4 | 0.00308 | -0.88235 |
| BX RT | -0.00849 | 0.00274 | 0.81095 |
| BY RT | -0.00337 | 5.49033E-4 | 0.94838 |
| Weighed RT | -0.00386 | 8.33763E-4 | 0.91069 |

**Table 9.** The linear fit of response time of pairs for Y_C

#### 4.1.2.4 Response time of CM_A

There are only 2 trials of AX-CPT for CM_A and these two trials are taken together with a 20 minutes meditation. Although lacking data, this is still a illustration of short time effects of meditation on cognitive ability. The effect is slightly negative in this case (Weighted RT slope is -0.00156). 75% of the response time are decreasing.

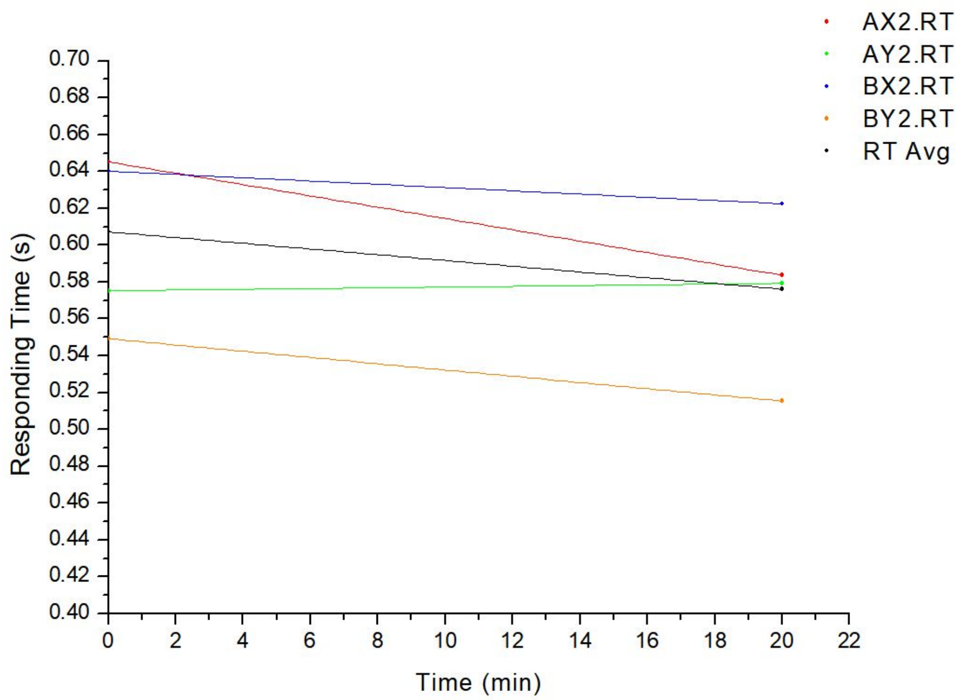


**Figure 22.** The response time of pairs for CM_A

| AXCPT RT | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX RT | -0.00308 | - | - |
| AY RT | 1.98593E-4 | - | - |
| BX RT | -8.87218E-4 | - | - |
| BY RT | -0.0017 | - | - |
| Weighed RT | -0.00156 | | |

**Table 10.** The linear fit of response time of pairs for CM_A

#### 4.1.2.5 Response time of CM_B

There are only 2 trials of AX-CPT for CM_B and these two trials are taken together with a 20 minutes meditation. Although lacking data, this is still a illustration of short time effects of meditation on cognitive ability. The effect is negative in this case (Weighted RT slope is -0.0046, the change is -0.092s). Almost all the response time decreased after the meditation.

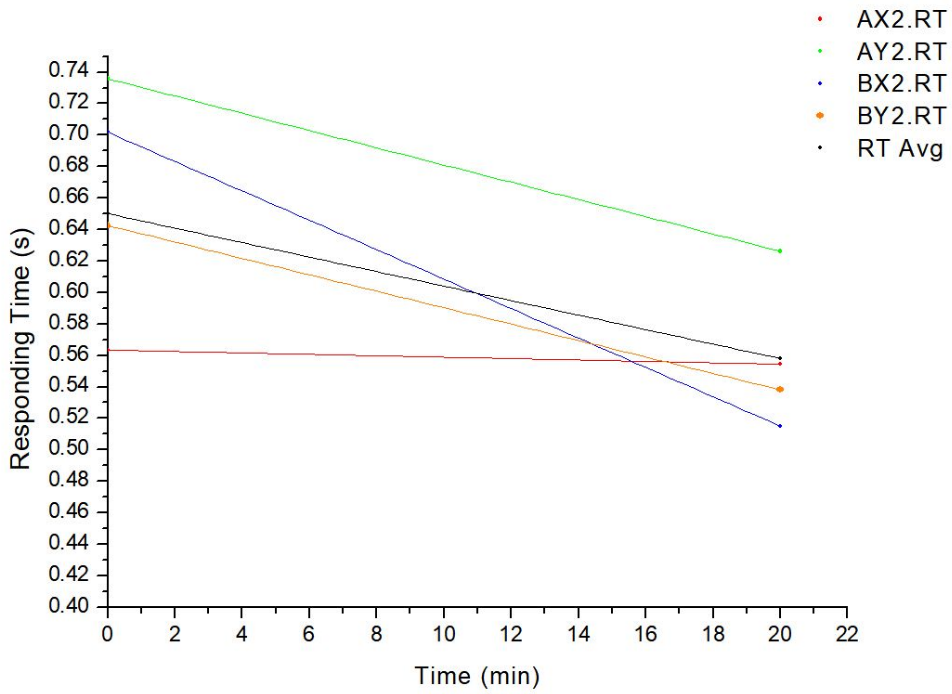


**Figure 23**. The response time of pairs for CM_B

| AXCPT RT | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX RT | -4.47989E-4 | - | - |
| AY RT | -0.00548 | - | - |
| BX RT | -0.00935 | - | - |
| BY RT | -0.00522 | - | - |
| Weighed RT | -0.0046 | | |

**Table 11.** The linear fit of response time of pairs for CM_B

#### 4.1.2.6 Response time of CM_C

There are only 2 trials of AX-CPT for CM_C and these two trials are taken together with a 20 minutes meditation. Although lacking data, this is still a illustration of short time effects of meditation on cognitive ability. The effect is negative in this case (Weighted RT slope is -0.00265, the change is -0.053s). All the response time decreased after the meditation.

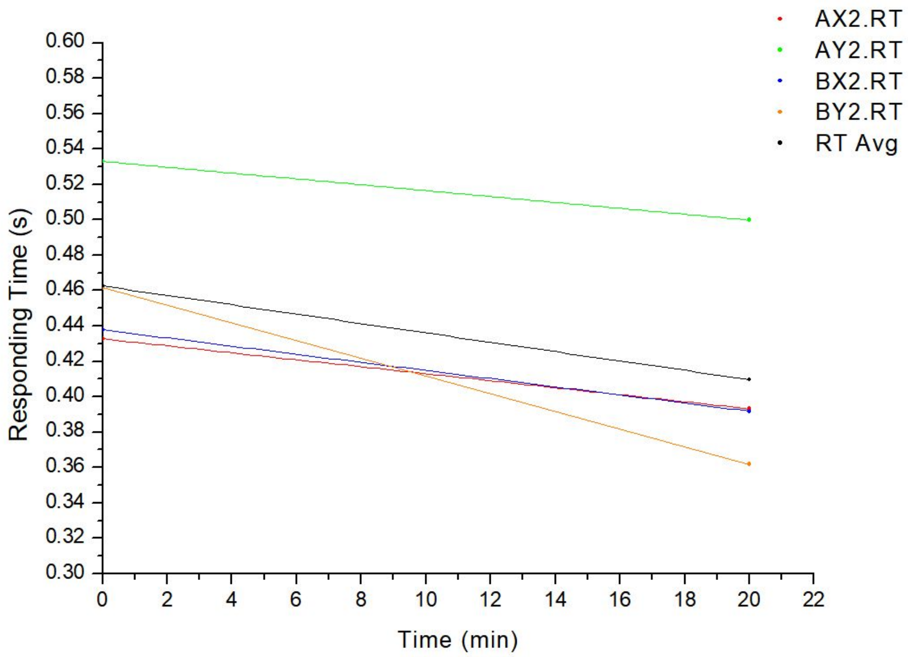


**Figure 24**. The response time of pairs for CM_C

| AXCPT RT | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| AX RT | -0.00198 | - | - |
| AY RT | -0.00166 | - | - |
| BX RT | -0.0023 | - | - |
| BY RT | -0.00499 | - | - |
| Weighed RT | -0.00265 | | |

**Table 12.** The linear fit of response time of pairs for CM_C

### 4.2 O-SPAN Results

The O-SPAN result consists of the total ospan absolute score and the correct rate of mathematical problems. The working solute score is the number of fully matched inputs of previously shown letters in sequence when the participant is doing the mathematical problems. The correct rate of mathematical problems must be over 85% for the memory test to be valid.

### 4.2.1 The O-SPAN Absolute Score

#### 4.2.1.1 The O-SPAN absolute score of Y_A, Y_B, Y_C and CM_C

In this study the yoga group (Y_A, Y_B and Y_C) and CM_C in the control/meditation group has done O-SPAN test for more than 2 sessions. So their data are put together for examination of yoga/meditation effecs in relatively longer period. As shown in the graph, the whole yoga group showed a decrease in O-SPAN absolute score, which is quite counterintuitive, and different participants showed significant discrepancy in working memory span: some participants are getting high score every time while the others consistently struggle between 0 to 10. However, due to the lack of data, the decrease might be a result of inadequacy in number of trials for participants with better performances.

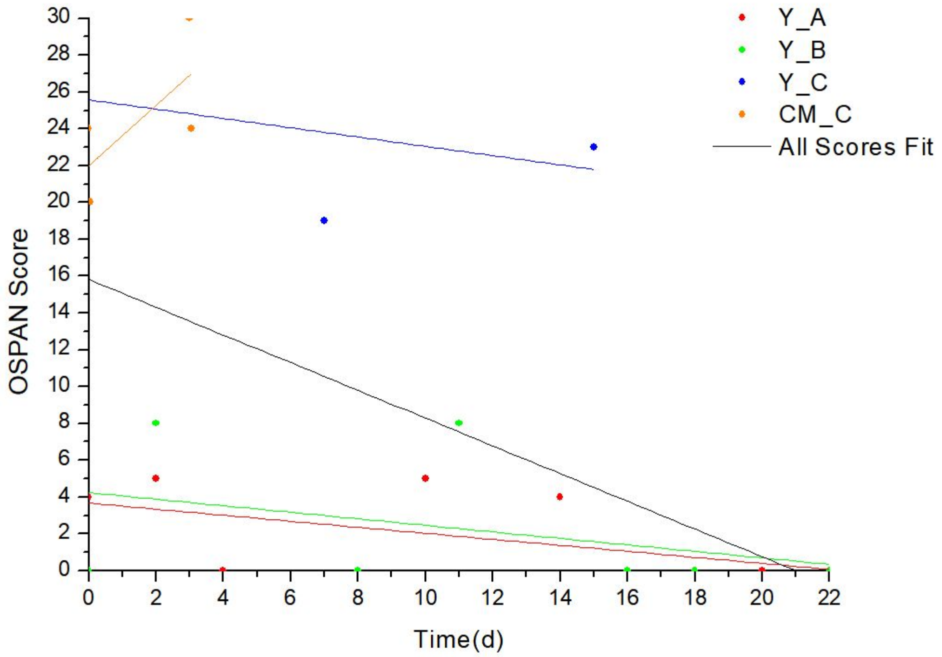


**Figure 25.** The O-SPAN absolute score of Y_A, Y_B, Y_C and CM_C

| O-SPAN Long | Slope | Standard Error (Slope) | Adj. R-Square | Mean |
|---|---|---|---|---|
| Y_A | -0.16385 | 0.08963 | 0.2065 | 1.8 |
| Y_B | -0.17734 | 0.19685 | -0.03241 | 2.28571 |
| Y_C | -0.25247 | 0.4612 | -0.30454 | 24 |

| | | | | |
|---|---|---|---|---|
| CM_C | 1.63843 | 1.22078 | 0.21079 | 24.5 |
| Total | -0.75314 | 0.25553 | 0.2426 | |

**Table 13**. The linear fit of trials and O-SPAN absolute score of Y_A, Y_B, Y_C and CM_C

#### 4.2.1.2 The O-SPAN absolute score of CM_A, CM_B, CM_C and CM_C2

In this study the the control/meditation group has done O-SPAN test two times with a separation of 20 minutes meditation. So their data are put together for examination of meditation effecs in a short period. According to the graph, except for a two-time zero score, all participants showed decreased score after 20 minutes meditation.

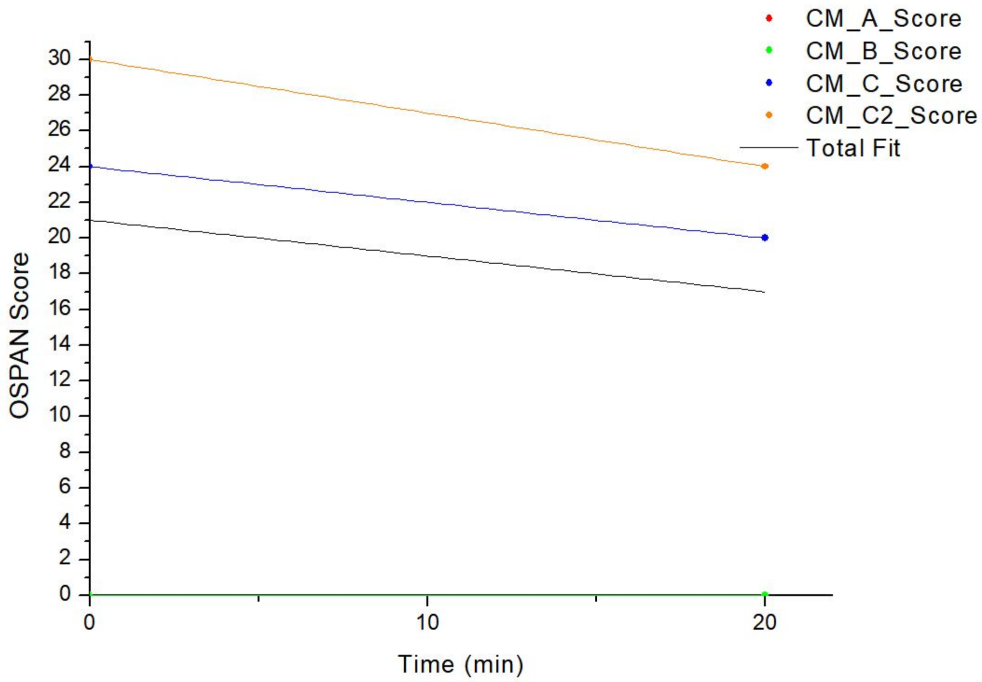


**Figure 26.** The O-SPAN absolute score of CM_A, CM_B, CM_C and CM_C2

| O-SPAN Short | Slope | Standard Error (Slope) | Adj. R-Square | Mean |
|---|---|---|---|---|
| CM_A | -0.3 | - | - | 27 |
| CM_B | 0 | - | - | 0 |
| CM_C | -0.2 | - | - | 22 |
| CM_C2 | -0.3 | - | - | 27 |

| | | | | |
|---|---|---|---|---|
| Total | -0.2 | 0.45826 | -0.13077 | |

**Table 14.** The linear fit of trials and O-SPAN absolute score of CM_A, CM_B, CM_C and CM_C2

### 4.2.2 The O-SPAN Math Score (Correct Rate)

#### 4.2.2.1 The O-SPAN math score of Y_A, Y_B, Y_C and CM_C

As for the longer period group, there is a slight decrease in the correct rate of O-SPAN math problems.

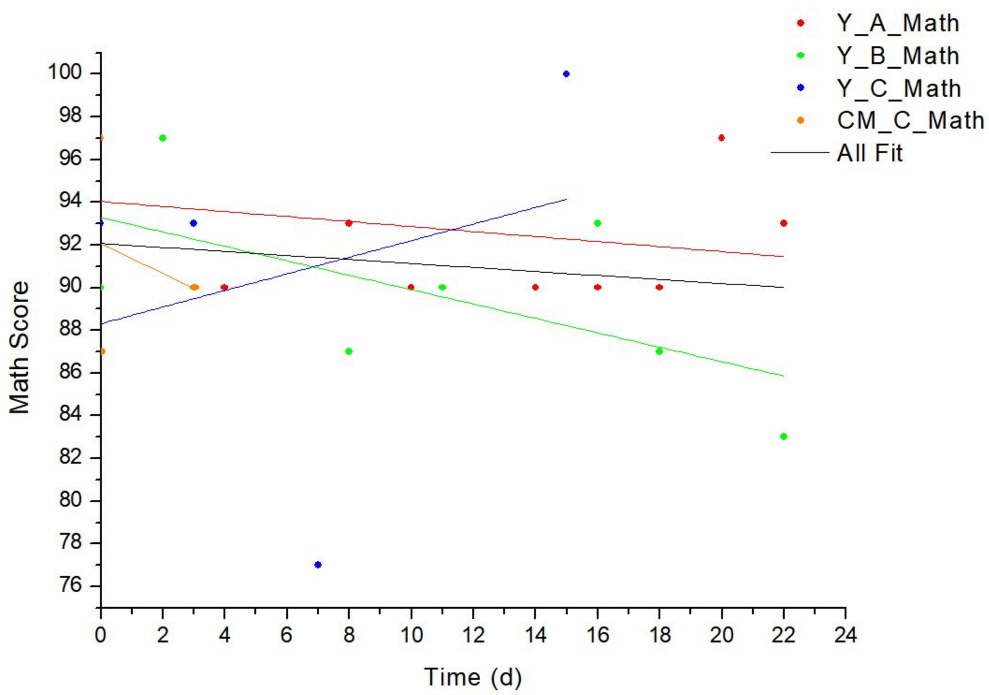


**Figure 27.** The O-SPAN math score of Y_A, Y_B, Y_C and CM_C

| O-SPAN Math Long | Slope | Standard Error (Slope) | Adj. R-Square | Mean |
|---|---|---|---|---|
| Y_A | -0.11719 | 0.13939 | -0.03367 | 92.7 |
| Y_B | -0.33744 | 0.19537 | 0.24841 | 89.57143 |
| Y_C | 0.38856 | 1.02361 | -0.39919 | 90.75 |
| CM_C | -0.69425 | 1.66078 | -0.37947 | 91 |

| Total | -0.09371 | 0.13348 | -0.02159 | |
|---|---|---|---|---|

**Table 15.** The linear fit of trials and O-SPAN math score of Y_A, Y_B, Y_C and CM_C

### 4.2.2.2 The O-SPAN math score of CM_A, CM_B, CM_C and CM_C2

With respect to the short period group, there is a decrease in the correct rate of O-SPAN math problems, an average drop of 4% after 20 minutes meditation.

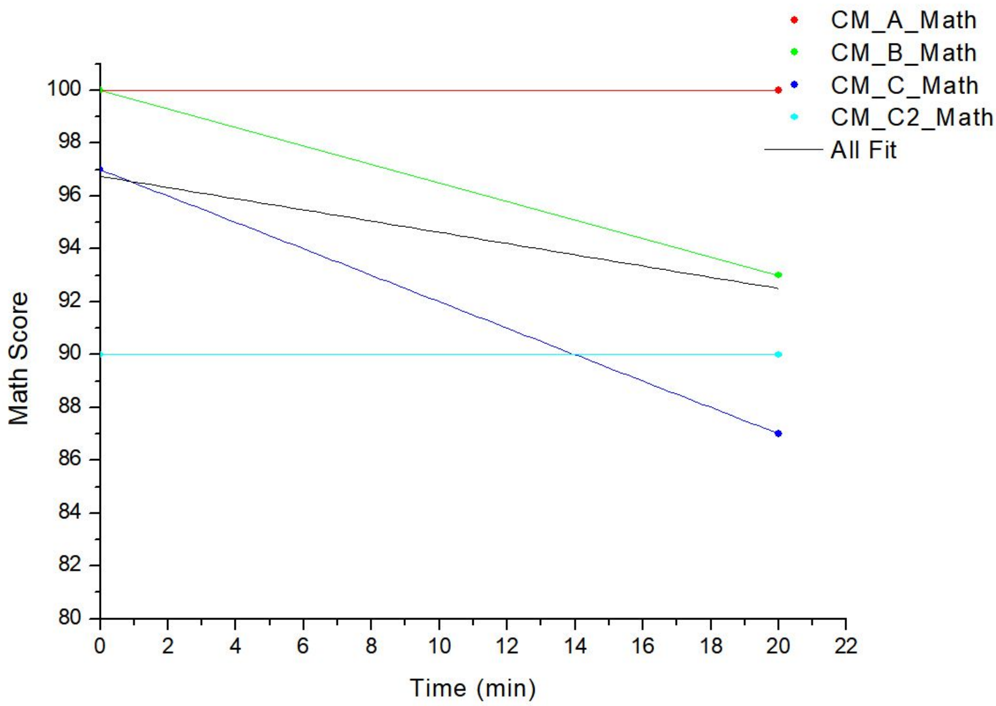


**Figure 28.** The O-SPAN math score of CM_A, CM_B, CM_C and CM_C2

| O-SPAN Math Short | Slope | Standard Error (Slope) | Adj. R-Square | Mean |
|---|---|---|---|---|
| CM_A | 0 | - | - | 100 |
| CM_B | -0.35 | - | - | 96.5 |
| CM_C | -0.5 | - | - | 92 |
| CM_C2 | -0.2125 | - | - | 90 |
| Total | -0.2 | 0.45826 | -0.13077 | |

**Table 16.** The linear fit of trials and O-SPAN math score of CM_A, CM_B, CM_C and CM_C2

### 4.2.3 The Number of Trials and Average O-SPAN Total Score.

It is worth noting in the experiment that participants with better O-spans are more likely to skip sessions or withdraw from the study, here is the relation between number of trials for a participant and the corresponse average O-SPAN total scores. The trend is negative with a linear fit slope of -2, which is as expected (although R is low, suggesting that this is not a linear distribution).

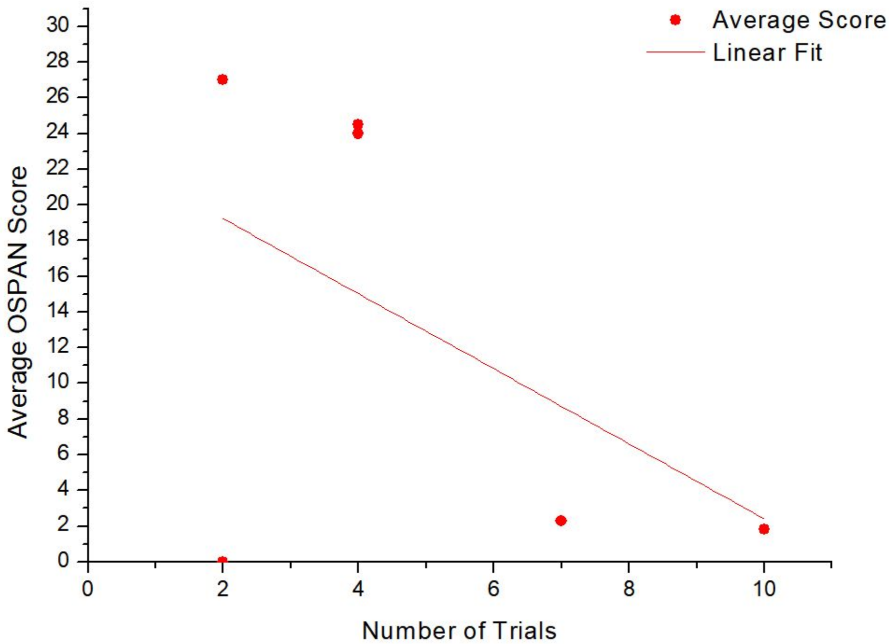


**Figure 29.** The average OSPAN absolute score and the respective number of trails for each participant

| O-SPAN Lazy | Slope | Standard Error (Slope) | Adj. R-Square |
|---|---|---|---|
| Trials | -2.10234 | 1.81325 | 0.06442 |

**Table 17.** The linear fit of average OSPAN absolute score and the respective number of trails for each participant

# 5. Discussion and Conclusion

## 5.1 Control/Meditation Group, Yoga Group and Test Performance

The control/meditation group as a whole can be seen as a short period meditation experiment. Although more data are necessary to have statistical significance, the results still suggests that a 20 minutes meditation will help decrease the response time for a short period (as shown in AX-CPT RT results), while the effects on cognitive control is unstable and ambiguous (as shown in AX-CPT correct rate). As for working memory ability, the results suggested that effects are negative: both the math score and O-SPAN absolute score dropped immediately after the meditation. This finding suggests that meditation might (in a short period) increase the arousal state in some part of mechanism of the brain while inhibit the others.

In terms of the yoga group, effects of yoga on relative longer periods (typically days) are not significant in general in cognitive control correct rate and the response time, although for some specific question (e.g. BX pair) and participant there seemed to be a relevance. There is also no clear link between yoga and O-SPAN math correct rate, while every participant in the yoga group had a drop of O-SPAN total scores with more yoga trials. This counterintuitive result however, might be the result of external factors as there was no control group in three of the four weeks.

The huge discrepancy in digits of working memory span among college students is observed in the experiment, there seemed to have no middle ground between high performance and very low performance - the participants were not using any memory knacks so this is a reflection of a distribution (discrete distribution) unlike (normal distribution of ) height or sport gifts. More investigations could be conducted to find the decisive (genetic) factor of working memory. In addition, people with higher working memory capacity are more likely to lack perseverance in this experiment, psychological and behavioral reasons might be considered to analyze the phenomenon.

## 5.2 Comparison with Other Studies

While many studies suggest meditation and yoga could have short/long term effects on mental health and cognitive ability, sometimes the effects are insignificant even for a relatively large sized group. White (2012) conducted a research ‘to investigate the efficacy of mindfulness training through 8-week yoga with school-age girls to reduce perceived stress, enhance coping abilities, self-esteem, and self-regulation’, yet they found no significant differences in self-esteem and stress level between control group and the intervention group. Velikonjaa (2010) investigated influence of yoga on cognitive function, spasticity, mood and fatigue in 20 patients with sclerosis in 10 weeks and no significant improvements in spasticity were found. It is unsurprising that this project didn’t find any concrete evidence of long-term effects of yoga on mental health as the time span and number of participants are so limited.

### 5.3 Further Improvements

The primary shortage for the study is the lack of participants. The was no valid control and experimental group. In consequence, no clear conclusion can be drawn from a statistical analysis of results. To further investigate the long-term effects of yoga on cognitive function, more participants and longer period of yoga practices are required.

It is also important to give more attention to the effectiveness of mindfulness meditation on cognitive function in a short period, as the dropped OSPAN score contradicts what was previously observed in longer term from other experiments. In addition, separate tests for response time should be adopted for comparison to tell the difference of response time in and out of a cognitive control test.

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