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Attentional networks and mindfulness:
investigations through multiple indexes

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Introduction

A reciprocal relation between attention and awareness is crucial for adaptive behavior. However, for investigating these relationships could be important to take into consideration the different components that constitute the attentional system. According to Posner and Petersen' model (Posner, 1994; Posner and Petersen, 1990), three different cognitive functions could be distinguished in human attention which are sub-served by three independent (although coordinated) neural systems: alerting responses, orienting to sensory stimulation and executive control of performance. The Alerting network is aimed at achieving and maintaining a state of high sensitivity to incoming stimuli and is related to the performance in tasks that involve both phasic and tonic alertness; the Orienting network is involved in the selection of information from the sensory input; the Executive control network is defined as involving the mechanisms for resolving cognitive conflict. As mindfulness meditation has been described as "the intentional cultivation of a non-judgmentally awareness that arise through paying attention, on purpose, in the present moment" (Kabat-Zinn, 1990; Kabat-Zinn, 2003), a putative candidate mechanism for its effects is a modification in attentional processing. This doctoral dissertation analyses the influence of mindfulness meditation on attentional performance. More specifically, in Chapter 1, theories and models of attention are introduced subdivided in four macro areas: Selective attention, Divided attention, Search and Signal detection and vigilance. In addition, Posner's model of attention is presented as the main core of this final work. This model, one of the most influent in attention literature, postulates that distinct areas of the brain underlie distinct attentional processes. In 2002, Fan and collaborators developed the Attention Network Test (ANT) in order to measure these attentional functions separately. Finally, a series of evolutions of this task, that have been proposed and developed in the last decades, are described in detail. In Chapter 2, mindfulness definition is introduced together with its historical background. Buddhist roots and Western Psychology overlap in theory and practice. Operational definition and the three-component model of mindfulness are important constructs that permit us to specify each component in terms of specific behaviors, experiential manifestations, and implicated psychological processes (Bishop et al., 2004). Furthermore, in Western world, mindfulness-based interventions are becoming widely accepted methods of addressing the symptoms associated with many commonly experienced mental health problems and/or emotional disorders.

Although these approaches involve mindfulness techniques, there are small differences between each modality that are here described in detail. Moreover, self-report assessments of mindfulness are convenient and efficient and can provide reliable and valid information if they are well constructed for the populations in which they will be used. The most important mindfulness questionnaires are described, highlighting the assessment used in this dissertation: the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006). Finally, neuroscience of mindfulness is introduced as a new way to explore whether and how our brain is affected by this kind of practice. In Chapter 3, two experiments are presented. The main goal of Experiment 1 is to investigate attention improvements of Mindfulness-Based Stress Reduction training (MBSR; Kabat-Zinn, 1990) compared to a Control group, using the Attention Network Test for Interactions-Vigilance (ANTI-V; Roca et al., 2011), that includes a direct measure of executive vigilance together with the classical attentional networks, introduced above, with the intent to better understand awareness strategies used by our attentional system. The aim of Experiment 2 is to assess the relationship between mindfulness facets of FFMQ and the Attention Network Test for Interactions-Vigilance. In Chapter 4, two more experiments are presented. The main goal of Experiment 3 is to replicate results from Luna et al., (*In preparation*). The authors designed a task (Attention Network Test for Interactions and Vigilance - executive and arousal components (ANTI-Vea) that could measure simultaneously the functioning of the typical attentional networks (phasic alertness, orienting and executive control), together with two different components of vigilance (executive –detection of infrequent signals-, and arousal –immediate reaction without response control-). The aim of Experiment 4 is to investigate whether and how FFMQ mindfulness facets interacts with attentional performance using ANTI-Vea task. Finally, a general discussion is presented. The general discussion focuses on overall results from the four experiments introduced above together with limitations and future directions.

Chapter 1
The nature of attention

1.1. Theories and models of attention

In *Principles of Psychology* William James defines attention as:

> *"[Attention] is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thoughts. … It implies withdrawal from some things in order to deal effectively with others"*

Attention refers to how we actively process specific information in our environment from the enormous amount of stimuli available through our senses, our stored memories, and our other cognitive processes (De Weerd, 2003a; Rao, 2003). Attention allows us to use our limited mental resources judiciously. By dimming the lights on many stimuli from outside (sensations) and inside (thoughts and memories), we can highlight the stimuli that interest us. This heightened focus increases the likelihood that we can respond speedily and accurately to interesting stimuli. Literature reports four functions of attention: *selective attention, divided attention, search, signal detection and vigilance*. Each of these functions have its neuroscientific studies and explanatory models. For instance, when we talk about selective attention we refer to our capacity to attend to some stimuli and ignore others, as when we pay attention on reading and ignore such stimuli as a nearby TV program; divided attention is the capacity to allocate our available attentional resources on performing more than one task, as when we are driving and listening to the radio at the same time; search is when we try to find a signal among distractors, as when we are finding our keys in our bag and signal detection and vigilance refer to our capacity to detect the appearance of a particular stimulus, as when air traffic controllers keep an eye on all traffic near and over the airport.

1.1.1. Selective attention

There are several theories studied selective attention belonging to the group of "filter" theories or "bottleneck" theories. A filter blocks some of information going through and thereby selects only a part of a total information to pass through to the next stage. A bottleneck slows down information passing through. According to one of the earliest theory of attention, we filter information right after we notice it at the sensory level (Broadbent, 1958). Broadbent's model argued that information from all of the stimuli presented at any given time enters a sensory buffer. One of the inputs is then selected on the basis of its physical characteristics for further processing by being allowed to pass through a filter. Because we have only a limited capacity to process information, this filter is designed to prevent the information processing system from becoming overloaded. The inputs not initially selected by the filter remain briefly in the sensory buffer, and if they are not processed they decay rapidly. Broadbent assumed that the filter rejected the non-shadowed or attended message at an early stage of processing. Hence, Broadbent's model suggests that the selection of material to attend to (that is, the filtering) is made early, before semantic analysis. Broadbent's theory was supported by Colin Cherry's findings that sensory information sometimes may be noticed by an attended ear if it does not have to be processed elaborately (e.g., you may notice that the voice in your unattended ear switches to a tone) but information requiring higher perceptual processes is not noticed if not attended to (e.g., you would likely not notice that the language in your unattended ear switches from English to German). Instead, for selective filter models (Moray, 1959; Wood & Cowan, 1995) the selective filter blocks out most information at the sensory level. But some personally important messages are so powerful that they burst through the filtering mechanism. Anne Treisman proposed her selective attention theory in 1964. Her theory is based on the earlier model by Broadbent. Treisman also believed that this human filter selects sensory inputs on the basis of physical characteristics. However, she argued that the unattended sensory inputs (the ones that were not chosen by the filter and remain in the sensory buffer) are attenuated by the filter rather than eliminated. In Attenuation model (Treisman, 1964), attenuation is a process in which the unselected sensory inputs are processed in decreased intensity. For instance, if you selectively attend to a ringing phone in a room where there's TV, a crying baby, and people talking, the later three sound sources are attenuated or decreased in volume. However, when the baby's cry goes louder, you may turn your attention to the baby because the sound input is still there, not lost. Treisman's selective attention theory involves a later filtering mechanism. Instead of blocking stimuli out, the filter merely weakens (attenuates) the strength of stimuli other than the target stimulus step by step. Deutsch and Deutsch (1963; Norman, 1968) developed a model, in which the location of the filter is even later, which explained that all information, both attended and unattended, undergo analysis for meaning. After such analysis, selection of a sensory input takes place. One factor that has a major effect on selecting the input is the relevance of the information during the time of processing. They suggested that stimuli are filtered out only after they have been analyzed for both their physical properties and their meaning. This later filtering would allow people to recognize information entering the unattended ear. For example, they might recognize the sound of their own names or a translation of attended input (for bilinguals). Both early and late selection theories have data to support them. In his influential book *Cognitive Psychology* (1967), Ulric Neisser proposed that the whole idea of a "filter" was wrong. It was too passive, suggesting that the cognitive system sits back and receives information without seeking it out. If we view the thought process as a *construction*, then selective attention results from what we *seek*, not what we fail to filter out. Neisser synthesized the early-filter and the late-filter models and proposed that there are two processes governing attention: *pre-attentive processes* and *attentive, controlled processes*. The first ones are rapid and occur in parallel. They can be used to notice only physical sensory characteristics of the unattended message. But they do not discern meaning or relationships. The last ones occur later. They are executed serially and consume time and attentional resources, such as working memory. They also can be used to observe relationships among features. They serve to synthesize fragments into a mental representation of an object. A two-step model could account for Cherry's, Moray's, and Treisman's data. The model also nicely incorporates aspects of Treisman's signal-attenuation theory and of her subsequent feature-integration theory. This theory has become very influential (Treisman & Gelade, 1980; Treisman & Schmidt, 1982). The author suggested that the individual features that make up an object (its color, motion, orientation, and so on) are encoded separately and in parallel by pre-attentive cognitive mechanisms. However, in order to perceive a whole object, the observer needs to 'glue together' (or integrate) these separate features, using visual attention. The feature-detection process may be linked to the former of the two processes (i.e., speedy, automatic processing). Her feature-integration process may be linked to the latter of the two processes (i.e., slower, controlled processing). These early theories of attention are all related to the selection of a subset of sensory information due to a limited capacity for information processing. One early model featured a "Supervisory Attention System" to account for the willed and automatic control of behavior (Norman & Shallice, 1986). Cognitive control is a top-down modulation of cognitive processes based on higher-order representations such as goals or plans. Also called executive control, this process can inhibit automatic responses and influence working memory. Cognitive control supports flexible, adaptive responses and complex goal-directed thought. According to this model, willed and automatic actions are controlled at different levels depending on the degree of task difficulty and complexity. When the action involves a well-learned, rehearsed or automatic response, the control operates at a lower level (contention scheduling mechanism) and an appropriate action/response is selected by lateral inhibition of competing response sequences (schemas). When the action/response is novel or complex, an additional system (supervisory system) is required for selection of a desired response sequence. Attention can thus be thought of as subserving cognitive control by modulating information processing in a goal-consistent manner, via the attentional functions. Further, in her Perceptual Load Theory (1995) Lavie suggested that the locus of selection is dependent on the perceptual load (amount of potentially task-relevant information) of the task in question. When the perceptual load of a task is low, and does not exceed perceptual capacity, distractors are processed (late selection). However, when the perceptual load of a task is high, irrelevant distractors are not processed (early selection). In other words, when perceptual load is low, there is a need for cognitive control mechanisms to maintain an adequate level of task performance (Lavie et al., 2004). Thus, attention, apart from selection processes, also incorporates elements of flexibility required for adjusting the efforts to tackle a task more effectively (Lavie & Cox, 1997). This flexibility seems to depend on emotion and awareness.

1.1.2. Divided attention

In order to understand our ability to divide our attention, researchers have developed capacity models of attention. These models help to explain how we can perform more than one attention-demanding task at a time. There are two different kinds: one kind of model suggests that there is one single pool of attentional resources that can be divided freely, and the other model suggests that there are multiple sources of attention (McDowd, 2007). Kahneman's model of divided attention (Kahneman, 1973) is based around the idea of mental efforts. This is a description of how demanding the processing of a particular input might be. Some tasks might be relatively automatic (in that they make few demands in terms of mental effort) despite the fact they have a high information load. Therefore, Kahneman proposes that some activities are more demanding (and therefore require more mental effort than others); the total available processing capacities may be increased or decreased by other factors such as arousal. Arousal is a degree of physiological excitation, responsivity, and readiness for action, relative to a baseline. For Kahneman, arousal has a determining effect on performance. Extreme states of arousal can degrade performance, as it permits too many distractions. Several activities can be carried out at the same time, provided that their total effort does not exceed the available capacity and rules or strategies exist which determine allocation of resources to various activities and to various stages of processing. Attentional capacity will, therefore, reflect the demands made at the perceptual level, the level at which the input is interpreted or committed to memory and the response selection stage. Attentional-resources theory has been criticized severely as overly broad and vague (e.g., Navon, 1984). Filter and bottleneck theories of attention seem to be more suitable metaphors for competing tasks that appear to be attentionally incompatible, like selective-attention tasks or simple divided-attention tasks. Although attentional-resources theory is more adequate at explaining divided attention among simple tasks, multiple resources theory is another, more accurate metaphor for explaining divided attention on complex tasks. Multiple resources theory states that as each complex task is automatized, performing that task requires less of the individual's limited-capacity attentional resources (Sternberg, Robert J.; Sternberg, Karin (2012). Cognitive Psychology (Textbook)).

1.1.3. Search

Another important line of investigations is about search. Search refers to a scan of the environment for particular features—actively looking for something when you are not sure where it will appear. Visual search is the common task of looking for something in a cluttered visual environment. The item that the observer is searching for is termed the *target*, while non-target items are termed *distractors*. The number of targets and distractors affects the difficulty of the task. Display size is the number of items in a given visual array (it does not refer to the size of the items or even the size of the field on which the array is displayed.). The display-size effect is the degree to which the number of items in a display hinders (slows down) the search process. When studying visual-search phenomena, investigators often manipulate the display size. They then observe how various contributing factors increase or decrease the display-size effect. Distracters cause more trouble under some conditions than under others. Suppose we look for an item with a distinct feature like color or shape. We conduct a *feature search*, in which we simply scan the environment for that feature (Treisman, 1993; Weidner & Mueller, 2009). Instead, in a *conjunction search*, we look for a particular combination (conjunctionjoining together) of features. In the last decades, three theories tried to explain search processes: feature-integration theory, similarity theory, and guided search theory. Anne Treisman's Feature Integration Theory (FIT), first proposed in 1980, holds that attention is critical to the formation of bound representations of objects and, by extension, it proposes that attention is critical to our conscious experience of those bound representations. In FIT the visual system first decomposes the visual scene into its composite features, arrayed in a set of 'feature maps'. The pre-attentive description of a scene or object comprises a list of such features. The term 'pre-attentive' has been controversial, but it can be operationally defined here as the representation of a stimulus before selective attention is directed to that stimulus. In FIT, the approximate position of each feature is recorded on its pre-attentive feature map. For example, if the visual scene contains two red objects, the feature map corresponding to redness would be activated at two points roughly corresponding to the locations of the red objects. If each feature were associated with a precise region in space, this might solve the binding problem. Features that correspond to the same region in space could be automatically conjoined, thus guaranteeing veridical perception. There is some neuropsychological support for Treisman's model. For example, Nobel laureates David Hubel & Torsten Wiesel (1979) identified specific neural feature detectors. These are cortical neurons that respond differentially to visual stimuli of particular orientations (e.g., vertical, horizontal, or diagonal). More recent research has indicated that the best search strategy is not for the brain to increase the activity of neurons that respond to the particular target stimuli; in fact, the brain seems to use the more nearly optimal strategy of activating neurons that best distinguish between the target and distracters while at the same time ignoring the neurons that are tuned best to the target (Navalpakkam & Itti, 2007; Pouget & Bavelier, 2007). Duncan & Humphreys (1989) investigated search performance for the letters L and T presented at various orientations. They found that in addition to target-background similarity, a major factor determining search efficiency is the similarity among the background elements. Thus, searching for upright L among inverted Ls is markedly easy than searching for that same target among Ls presented at several orientations. This effect of background homogeneity interacts with target-background similarity; it produces a marginal effect when the target is clearly distinguishable from the background, but become increasingly important as the target and distractors become more similar. To account for these findings, Duncan and Humphreys formulated a Similarity Theory of visual search. The theory holds that response times for detecting a target are not influenced by display size as long as non-target items attract no resources. Otherwise, increasing the number of non-targets will be harmful, because it reduces resource availability for the target. The more closely a non-target matches a target template, the greater the amount of resources devoted to it. Thus, the more similar the target and distractors are, the less efficient is the search for the target. Furthermore, the more heterogeneous the distractors, the less likely is it that a simple target description will exclude them all. More elaborate descriptions should lead to poorer selection, either because of the complexity required for the matching operation or because the more attributes the template needs to possess the more likely it is to share attributes with each non-target, consequently disrupting selective search. Finally, Guided Search Theory (Cave & Wolfe, 1990; Wolfe, 2007) is an intellectual heir of FIT. According to this model, the initial processing of basic features produces an activation map, in which each of the items in the visual display has its own level of activation. Suppose you were searching for red, horizontal targets. Feature processing would activate all red objects and all horizontal objects. Attention is then directed towards items on the basis of their level of activation, starting with those with the highest level of activation. It follows that distractors sharing at least one feature with the target are activated and slow down visual search, which is what was found by Treisman & Sato (1990). A problem with the original version of feature integration theory was that targets in large display are typical found faster than predicted. The activation-map notion provides a plausible way in which visual search can be made more efficients: stimuli not sharing any features with the target stimulus are ignored because they receive little or no activation.

1.1.4. Signal detection and vigilance

What if we have to discriminate between target (signal) and noise as well as when we do so for prolonged periods during which the stimulus is absent? Signal Detection Theory (SDT) evolved from the development of communications and radar equipment the first half of this century. It migrated to psychology, initially as part of sensation and perception, in the 50's and 60's as an attempt to understand some of the features of human behavior when detecting very faint stimuli that were not being explained by traditional theories of thresholds. From the beginning of the discipline, psychologists were interested in measuring our sensory sensitivity, how well we detect stimuli. The leading theory was that there was a threshold, a minimum value below which people could not detect a stimulus. The only problem was that no firm threshold could be established. Some people heard a faint background noise easily, while others completely missed loud noises nearby. The results were simply too inconsistent for there to be a standard threshold. So, researchers started looking for a new explanation. What they found was that the sensory sensitivity was a relationship between the strength of the signal and the level of alertness, and thus, signal detection theory was born. When we try to detect a target stimulus (signal), there are four possible outcomes: if a stimulus is presented and the person says yes, the trial is a "*hit*". If no stimulus is presented but the person still says yes, it is a "*false alarm*" (FA) and might indicate that the subject is motivated to guess. If a stimulus is presented and the person says no, it is a "*miss*" (d') and gives information on the subject's ability to detect the stimulus. Finally, if no stimulus is presented and the person says no, it is a "*correct rejection*" (β). The relative frequency of these four types of response are not all independent. For example when the signal is present the proportion of Hits and the proportion of Misses add up to one (because when the signal is present the subject can say either Yes or No). Likewise when the signal is absent, the proportion of FA and the proportion of Correct Rejection add up to one. Therefore all the information is given by the proportion of Hits and FAs. Even though the proportions of Hits and FAs provide all the information in the data, these values are hard to interpret because they crucially depend upon two parameters. The *first* parameter is the *difficulty* of the task: the easier the task the larger the proportion of Hits and the smaller the proportion of FAs. When the task is easy, we say that the signal and the noise are well separated, or that there is a large distance between the signal and the noise (conversely, for a hard task, the signal and the noise are close and the distance between them is small). The *second* parameter is the *strategy* of the participant: a participant who always says No will never commit a FA; on the other hand, a participant who always says Yes is guaranteed all Hits. A participant who tends to give the response Yes is called *liberal* and a participant who tends to give the response No is called *conservative* (Abdi, 2007). The concept of *Vigilance* (also called *sustained attention* or *tonic alert*) is highly related to SDT. Vigilance refers to a person's ability to attend to a field of stimulation over a prolonged period, during which the person seeks to detect the appearance of a particular target stimulus of interest. The study of vigilance has expanded since the 1940s mainly due to the increased interaction of people with machines for applications involving monitoring and detection of rare events and weak signals. Such applications include air traffic control, inspection and quality control, automated navigation, military and border surveillance, and lifeguarding. The systematic study of vigilance was initiated by Norman Mackworth during World War II. Mackworth authored "The breakdown of vigilance during prolonged visual search" in 1948 and this paper is the seminal publication on vigilance. Mackworth's 1948 study investigated the tendency of radar and sonar operators to miss rare irregular event detections near the end of their watch. Mackworth simulated rare irregular events on a radar display by having the test participants watch an unmarked clock face over a 2-hour period. A single clock hand moved in small equal increments around the clock face, with the exception of occasional larger jumps. This device became known as the Mackworth Clock. Participants were tasked to report when they detected the larger jumps. Mackworth's results indicated a decline in signal detection over time, known as a vigilance decrement. The participants' event detection declined between 10 and 15 percent in the first 30 minutes and then continued to decline more gradually for the remaining 90 minutes. Mackworth's method became known as the "Clock Test" and this method has been employed in subsequent investigations. Vigilance decrement is defined as "deterioration in the ability to remain vigilant for critical signals with time, as indicated by a decline in the rate of the correct detection of signals" (Parasuraman, 1986). Vigilance decrement is most commonly associated with monitoring to detect a weak target signal. Detection performance loss is less likely to occur in cases where the target signal exhibits a high saliency. For example, a radar operator would be unlikely to miss a rare target at the end of a watch if it were a large bright flashing signal, but might miss a small dim signal. Under most conditions, vigilance decrement becomes significant within the first 15 minutes of attention (Teichner, 1974), but a decline in detection performance can occur more quickly if the task demand conditions are high (Helton et al., 2007). This occurs in both experienced and novice task performers (Mackie, 1984). Vigilance had traditionally been associated with low cognitive demand and vigilance decrement with a decline in arousal pursuant to the low cognitive demand (Frankmann & Adams, 1962), but these views are no longer widely held. More recent studies indicate that vigilance is hard work, requiring the allocation of significant cognitive resources, and inducing significant levels of stress (Parasuraman & Davies, 1977).

1.2. Posner’s model of attention

For about a century thereafter, several theoretical models of attention have been put forward, one of which is that by Posner and Petersen. First of all, authors argued that they are three basic concepts about the attention system. The first is that the attention system is anatomically separate from processing systems, which handle incoming stimuli, make decisions, and produce outputs. The second concept is that attention utilizes a network of anatomical areas. The third is that these anatomical areas carry out different functions that can be specified in cognitive terms. According to Posner and collaborators' model, three different cognitive functions could be distinguished in human attention, which are sub-served by three independent (although coordinated) neural systems. First, the alertness network involves some fronto-parietal regions, mainly in the right hemisphere, and also some brain stem areas such as the locus coeruleus (Posner, 2008). This neural circuit is aimed at achieving and maintaining a state of high sensitivity to incoming stimuli and is related to the performance in tasks that involve both phasic and tonic alertness (see, for example, Posner, 2008; Sturm and Willmes, 2001). Second, the orienting network includes different areas of the parietal and frontal lobes, and it is involved in the selection of information from the sensory input (Fan et al., 2002). Third, the executive control network activates anterior areas of the frontal cortex, such as the anterior cingulate and the dorsolateral prefrontal cortex. This network is defined as involving the mechanisms for resolving cognitive conflict, and it could be efficiently assessed with the use of Stroop, Simon or flanker tasks (see, for example, Fan et al., 2002). Each of these networks is described below separately (Figure 1).

1.2.1. Alerting

As it has been suggested, one approach to the study of alerting is to use a warning signal prior to a target event to produce a phasic change in alertness (Petersen and Posner, 2012). When the warning cue appears there is a change from the resting state to a new state that involves preparation for detecting and responding to an expected signal. If the target requires a speeded response reaction time improves following a warning. This improvement is not due to a different information of the target, which is not changed by the warning signal, but to the change of speed in orienting attention and thus responding to the signal. Several approaches have been used to the study of tonic alertness. A long established approach to tonic alertness is to use a long and usually rather boring task to measure sustained vigilance. Vigilance tasks rely heavily on mechanisms of the right cerebral cortex (Posner & Petersen 1990). In the classic lesion data as well as in more recent imaging data there is the confirmation that tonic alertness is strongly lateralized to the right hemisphere. Our comprehension of the physiology and pharmacology underlying the alerting system has changed significantly. There is a strong evidence relating the neuromodulator norepinephrine (NE) to the alerting system. Locus coeruleus, the source of NE, is the brain area activated by a warning signal (Aston-Jones & Cohen, 2005). The changes during the time between warning and target reflect a suppression of ongoing activity thought to prepare the system for a rapid response. Contingent negative variation (CNV) (Walter, 1964) is a negative shift in scalp-recorded EEG, which often begins with the warning signal and may remain until there is the presentation of the target. In part, this negativity could arise from anterior cingulate and adjacent structures (Nagai et al., 2004) and may overlap the event-related response to the warning stimulus. An extensive imaging study (Sturm & Willmes, 2001) showed that a large common right hemisphere and thalamic set of areas are involved in both phasic and tonic alerting. Other imaging study, however, suggested that the warning signal effects rely more strongly on left cerebral hemisphere mechanisms (Coull et al., 2000; Fan et al., 2005). These differences in laterality found in tonic and phasic studies are still to reconcile.

1.2.2. Orienting

The orienting network is focused on the ability to prioritize sensory input by selecting a modality or location. Imaging literature, now, points out that anterior as posterior brain areas are involved in orienting. For example, human and animal studies have implicated the frontal eye fields (FEF) in this process (Corbetta et al., 1998; Thompson et al., 2005). In addition, also parietal areas have been implicated in related forms of processing. A series of imaging experiments by Corbetta & Schulman (2002) using cuing methodology in combination with event-related fMRI indicate two brain systems related to external stimuli. A more dorsal system including the FEFs and the interparietal sulcus followed presentation of an arrow cue and was identified with rapid strategic control over attention. When the target was miscued, subjects had to break their focus of attention on the cued location and switch to the target location. The temporoparietal junction (TPJ) and the ventral frontal cortex were involved in the switch and the latter was identified with the interrupt signal that allowed the switch to occur. Parietal regions were included in the ventral system but added a small set of frontal locations as well, particularly in the FEFs. In literature, some authors have argued that covert attention shifts are linked to the saccadic eye movement system (Rizzolatti et al., 1987), and neuroimaging studies using fMRI have shown that covert and overt shifts of attention involve similar areas (Corbetta et al., 1998). It is important, now, to connect the imaging and physiological results with other studies to provide more details on local computations. One strategy could be studying the pharmacology of each of the attention networks. For example, cholinergic systems arising in the basal forebrain appear to play a critical role in orienting; lesions of the basal forebrain in monkeys interfere with orienting attention (Voytko et al., 1994). Rat studies and monkey studies have been confirmed same observations: only the cholinergic system influence the orienting response (Everitt & Robbins, 1997; Stewart et al., 2001). The more ventral network including the TPJ seemed to be more active following the target and was thus identified as part of a network responsive to sensory events. Brain areas involved in orienting to visual stimuli seem to overlap strongly (within fMRI resolution) with those involved with orienting to stimuli in other modalities (Driver et al., 2004). Finally, anatomically the source of the orienting effect lies in the network of parietal, frontal, and subcortical areas mentioned above. The influence of attention is on the bottom-up signals arriving in sensory-specific areas. Attention to a target seems to reduce the influence of other competing stimuli.

1.2.3. Executive Control

In Posner et al., (1990), executive control was presented with the heading of target detection. Although it is possible to monitor for targets in many processing streams without too much difficulty, the moment of target detection produces interference across the system, slowing detection of another target (Duncan, 1980). Focal attention is a set of processes related to the limited capacity of attentional system and to awareness. Focal attentions may involve widespread connections from the midline cortex and the anterior cingulate cortex (ACC) to produce the global work space frequently associated with consciousness (Dehaene & Changeux, 2011). There is a strong association of target detection and awareness of the target with the medial frontal cortex and the adjacent ACC. Anterior cingulate cortex and related regions have been reliably activated when there is conflict. Focal attention explanation comes from activity found in the medial frontal/anterior cingulate in such diverse operations as perception of either physical (Rainville et al., 1997) or social (Eisenberger et al., 2003) pain, processing of reward (Hampton & O'Doherty 2007), monitoring or resolution of conflict (Botvinick et al., 2001), error detection (Dehaene et al., 1994), and theory of mind (Kampe et al., 2003). Some authors suggested that activity found during the performance of tasks was related to focal attention because trial-related activity in these regions was greater for targets than for nontargets, for conflict more than for nonconflict trials, and for errors more than for correct trials. Neuroimaging gives us strong evidence that conflict tasks such as the Stroop effect activate common areas of the anterior cingulate gyrus: the dorsal portion for more strictly cognitive tasks and the ventral area for emotion-related tasks (Botvinick et al., 2001; Bush et al., 2000). The common involvement of the anterior cingulate in attention and both emotion and cognitive control has provided one basis for the argument that the executive attention network is critical to these various functions. Both behavioral and resting state functional data suggest substantial development of the executive attention network between infancy and childhood. Although conflict resolution has been studied widely with normals, the anatomy of other functions remains to be thoroughly explored.

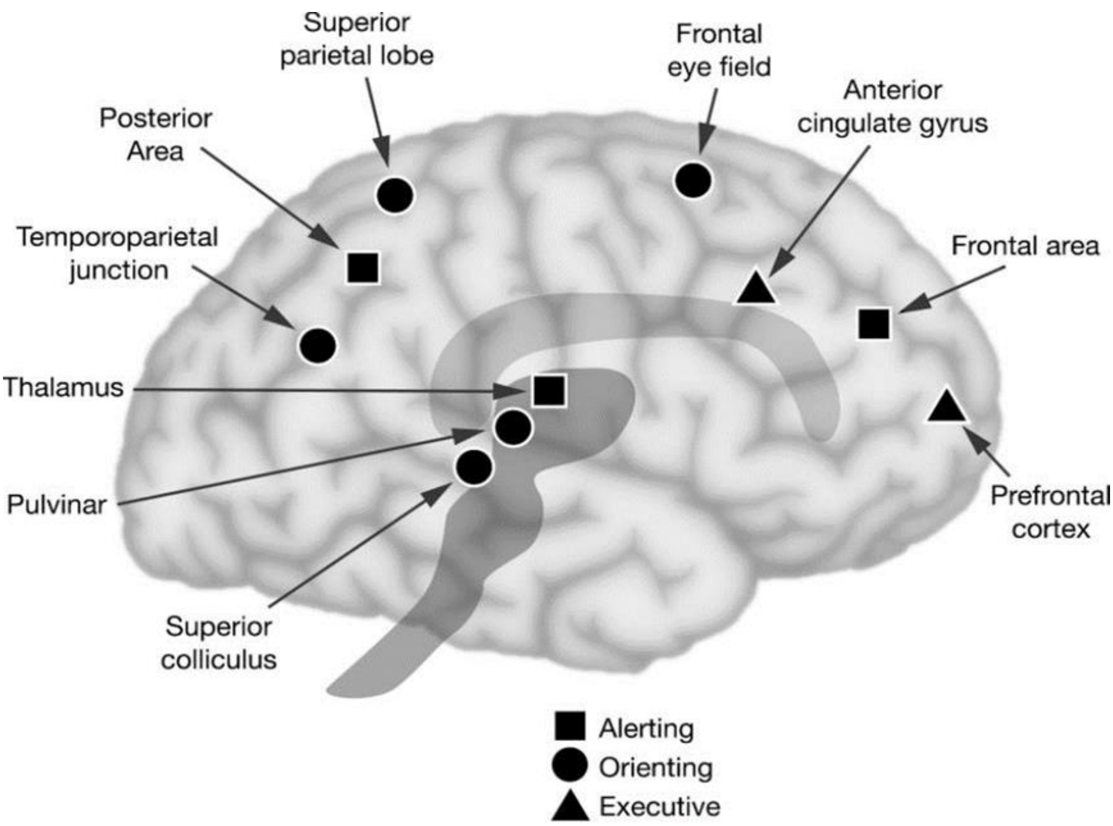

Figure 1.1 Anatomy of three attentional networks: alerting, orienting, and executive control (from Posner & Rothbart, 2007)

1.3. From ANT to ANTI-Vea: measuring attentional networks and vigilance

Alerting, orienting, and executive control are widely thought to be relatively independent aspects of attention that are linked to separable brain regions. In 2002, Fan and colleagues developed the Attention Network Test (ANT), based on a widely renowned neurocognitive model of human attention: the three attentional networks model proposed by Mike Posner and collaborators. The ANT combines *Cued Reaction Time Task* (CRRT; Posner, 1980) and *Flanker Task* (Eriksen & Eriksen, 1974) to differentiate independent attention components in one paradigm and has been widely employed in brain functional (Kellermann et al., 2011; Neuhaus et al., 2010), developmental (Ishigami et al., 2011; Konrad et al., 2005), genetic (Fossella et al., 2002; Posner et al., 2007), and psychiatric investigations (Adólfsdóttir et al., 2008; Bush, 2010) to test normal and abnormal attention abilities. The manipulations of cue and flanker type allow the calculation of response time (RT) difference scores assumed to represent the three attention networks. Participants indicate the direction of a central arrow that is flanked by four arrows (two per side) pointing in the same direction as the central arrow (congruent condition) or in the opposite direction (incongruent condition); in the neutral condition, either straight lines flank the central arrow or the central arrow is presented alone, depending on the study. The arrows are preceded by one of three types of cues (center cue, double cue, spatially informative cue; all of which are temporally informative) or no cue (a temporally uninformative condition). The center and double cues indicate that the arrow stimulus will occur soon, and the spatially informative cue is 100% predictive of target location. The ANT provides two measures of performance, response time (RT) and error rate (ER), and the three network scores are calculable within each of these measures. The alerting network score is calculated by subtracting the double cue conditions from the no cue conditions. These cue conditions are used because the double cue provides temporal information regarding the upcoming flanker display that the no cue condition does not, but both cue conditions are thought to represent a diffuse allocation of attention. The orienting network score is calculated by subtracting the valid cue condition from the center cue condition. The valid cue captures attention to the appropriate stimulus location for the upcoming flanker display, but in the center cue condition, attention will have to move to the flanker display when it appears either above or below fixation. The executive control network score is calculated by subtracting the congruent flanker condition from the incongruent condition. The distractors surrounding the center target in the incongruent condition result in more interference in the response selection process compared to the congruent condition. In the original report on the ANT, Fan and colleagues observed no significant correlations between any of the attention network scores (Figure 2). Hence, in 2004, Callejas and collaborators developed the Attention Network Test for Interactions (ANTI), a variation of the original ANT that provides more independent measures of the phasic alertness and orienting scores. To achieve this objective, the ANTI includes an auditory warning signal (instead of a visual cue) to independently assess phasic alertness. Also, the visual cues used to evaluate attentional orienting are not predictive of the location of the forthcoming targets, and thus only exogenous orienting attention is involved. The ANTI task allows a more independent testing of the three attentional networks, allows also measuring the interactions between the attentional networks and usually provides more reliable scores, particularly for phasic alertness. Although the three attentional networks are independent and based on different brain networks, they are acting in a constant mutual influence in order to produce efficient and adaptive behavior when their functioning is measured in a complex task. A further version of ANTI (Rueda et al, 2004) is a child-friendly version of ANT (using fishes instead of arrows) modified to study the development of the networks in children. In 2011, Roca and collaborators developed the Attention Network Test for Interactions and Vigilance (ANTI-V), a further variation of the ANTI in which a measure of vigilance is added. This measure evaluates tonic alertness (i.e., the ability to detect infrequent, unpredictable and unexpected stimuli) and it is obtained in addition to the usual phasic alertness, orienting and executive control scores. This new task provided a direct measure of vigilance. Participants were asked to detect infrequent targets by pressing a different key on the keyboard in order to test specific hypothesis on vigilance. At the same time, ANTI-V helped interpreting the phasic alertness score, since similar high phasic alertness scores can be associated with either an increased efficiency using warning signals or a decreased ability to maintain tonic attention. In addition, this task has a better control for differences in tonic alertness when comparing groups of healthy and/or patient participants, since such differences may modulate the functioning of other attentional functions (see chapter 3, Experiment 1, for more details). Finally, an ulterior version of ANT has been developed by Luna and colleagues (*In preparation*). The Attention Network Test for Interactions and Vigilance - executive and arousal components (ANTI-Vea) measure simultaneously the functioning of the typical attentional networks (phasic alertness, orienting and executive control), together with two different components of vigilance (executive –detection of infrequent signals-, and arousal –immediate reaction without response control-) (see Chapter 4, Experiment 1, for more details).

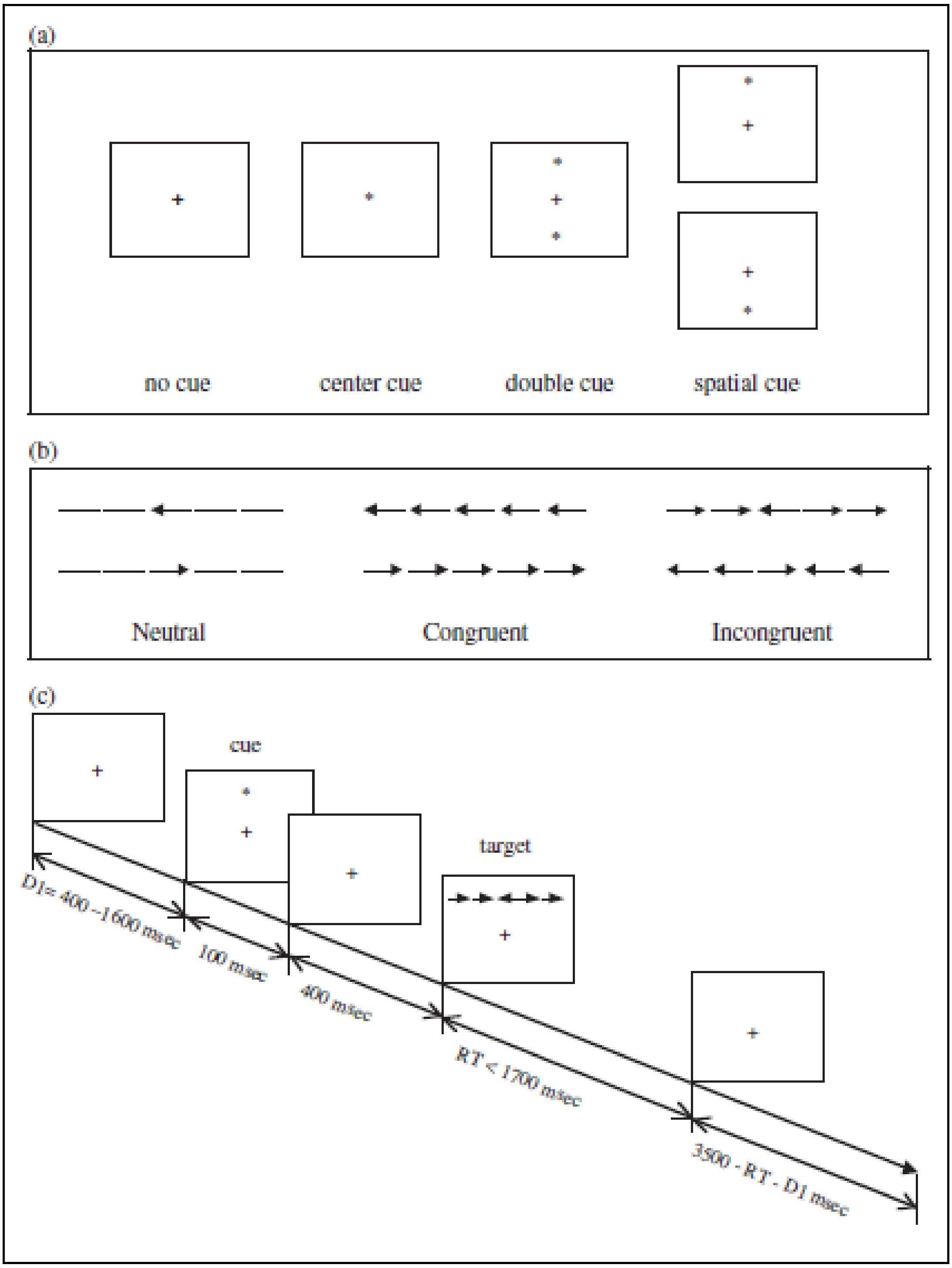

Figure 1.2 Experimental procedure. (a) The four cue conditions; (b) The six stimuli used in the experiment; and (c) An example of the procedure (Fan et al., 2002)

Chapter 2

Mindfulness: a new perspective of awareness

Hic: "Present moment never comes back…yesterday was yesterday and today is today"
Nunc: "I always say that we need to be mindfully present in every circumstance of time"
Hic: "And place!"
Nunc: "Of course Hic, fully awareness of every little perception of senses, mood states and every situation we are living needs our synergic fusion"
Hic: "Being always constantly, perfectly present to oneself"

2.1. Hic et nunc of awareness: origins of mindfulness

In the last decades, "mindfulness" has become cornerstone of a considerable attention by extended part of clinicians and experimental psychologists. The ontological concept has been described as "the intentional cultivation of a non-judgementally awareness that arise through paying attention, on purpose, in the present moment" (Kabat-Zinn, 1990; Kabat-Zinn, 2003). Historically, mindfulness has been called "the heart" of Buddhist meditation (Thera, 1962). The word *mindfulness* originally comes from the Pali word *sati*, which means having awareness, attention and remembering (Bodhi, 2000) and has been used to refer to psychological state of awareness, a practice that promotes this awareness, a mode of processing information and a characterological trait (Davis & Hayes, 2011). Mindfulness practices take a variety of forms, from a range of formal ones that are undertaken for varying periods of time on a regular basis, to informal ones that are aimed at cultivating a continuity of awareness in all activities of daily living (Kabat-Zinn, 2003). Mindfulness in contemporary psychology has been adopted as an approach for increasing awareness and responding skillfully to mental processes that contribute to emotional distress and maladaptive behavior (Bishop et al., 2004). It is, now, important to characterize the components of mindfulness that, in the last decades, were described by several models and constructs in order to understand why this practice could be so important for our well-being and health.

2.2. Mindfulness: a proposed operational definition

Bishop et al., (2004) propose a two-component model of mindfulness: the first one involving self-regulation of attention towards the immediate present moment, the second pertaining to the adoption of an orientation marked by curiosity, openness and acceptance. It is important, now, to describe every single component in terms of behavioral and experiential features and in terms of the implicated psychological processes.

2.2.1. Self-regulation of Attention

According to this model, mindfulness begins by bringing awareness to current experience—observing and attending to the changing field of thoughts, feelings, and sensations from moment to moment—by regulating the focus of attention. This leads to a feeling of being very alert to what is occurring in the here-and-now. It is often described as a feeling of being fully present and alive in the moment. Hence, it could increase skills of *sustained attention*. Sustained attention is the ability to direct and focus cognitive activity on specific stimuli. Sustained attention on the breath thus keeps attention anchored in current experience so that thoughts, feelings, and sensations can be detected as they arise in the stream of consciousness. Further, mindfulness could increase skills of *switching.* Switching is an executive function and a kind of cognitive flexibility that involves the ability to shift attention between one task and another. This ability allows a person to rapidly and efficiently adapt to different situations. Thus, one of the prediction of this model is that the development of mindfulness would be associated with improvements in sustained attention and switching, which can be objectively measured using standard tests. The self-regulation of attention also involves a direct experience of events in the mind and body (Teasdale, Segal, Williams, & Mark, 1995), that is, all thoughts or events are considered an object of observation, not a distraction. Mindfulness practices are thought to be associated with improvements in cognitive inhibition, particularly at the level of stimulus selection. The term cognitive inhibition refers to the ability to control or suppress irrelevant responses, and to adopt instead relevant and flexible responses. This can be objectively measured using tasks that require the inhibition of semantic processing (e.g., emotional Stroop; Williams, Mathews, & MacLeod, 1996). Furthermore, Bishop et al. argue that rather than observing experience through the filter of our beliefs, assumptions, expectations, and desires, mindfulness involves a direct observation of various objects as if for the first time, a quality that is often referred to as “beginner’s mind”. The prediction is that mindfulness practice should facilitate the identification of objects in unexpected contexts because one would not bring preconceived beliefs about what should or should not be present.

2.2.2. Orientation to Experience

Mindfulness is further defined by an orientation to experience that is adopted and cultivated in mindfulness meditation practices. People are instructed to make an effort to just take notice of each thought, feeling, and sensation that arises in the stream of consciousness. A stance of acceptance is taken toward each moment of one’s experience. Acceptance is defined as being experientially open to the reality of the present moment (Roemer & Orsillo, 2002). Acceptance turns out to be one of the most helpful attitudes to bring to mindfulness. Acceptance means perceiving your experience and simply acknowledging it rather than judging it as good or bad. Acceptance doesn’t mean resignation; it refers to your experience from moment to moment. Adopting a stance of curiosity and acceptance during mindfulness practices should eventually lead to reductions in the use of cognitive and behavioral strategies to avoid aspects of experience and would be expected to change the psychological context in which those objects are now experienced. Mindfulness can thus be further conceptualized as a process of investigative awareness that involves observing the ever-changing flow of private experience. People are instructed to avoid trying to produce a particular state (e.g., relaxation), but rather to just notice each object that arises in the stream of consciousness. Furthermore, Bishop and collaborators argue that monitoring the stream of consciousness in this manner over time would likely lead to increased cognitive complexity as reflected by an ability to generate differentiated and integrated representations of cognitive and affective experience. Further, mindfulness practices provide opportunities to gain insight into the nature of thoughts and feelings as passing events in the mind rather than as inherent aspects of the self or valid reflections on reality (Teasdale et al., 1995; Teasdale, 1999a, 1999b; Segal, Williams, & Teasdale, 2002).

2.3. Mindfulness and the three-component model

Shapiro et al., (2006) propose a three-component model (axioms) of mindfulness: *intention*, *attention* and *attitude*. The three axioms of mindfulness are not separate stages. They are interwoven aspects of a single cyclic process and occur simultaneously. Intention signifies the practitioner's personal vision, which shifts along a continuum 'from self-regulation, to self-exploration, and finally to self-liberation'; attention means developing the competencies of applied and sustained focus, and flexibility of focus; and attitude is an accepting, open and kind curiosity towards one's own experience. In the learning process, these internal behaviors are engaged to attend to the mind and body as it presents itself in the here and now, without habitual judgments and interpretations. Intention is *why* we practice. Attention is *what* we practice. Attitude is *how* we practice. This produces a shift in perspective called reperceiving, through which one gains an increased capacity for objectivity about one's own internal experience. This, in turn, increases self-regulation and self-management, creativity, and cognitive, emotional and behavioral flexibility. In scientific accounts across the different discourses of meditation and mindfulness, the shift has also been described as a "de-automatisation of the psychological structures that organize, limit, select and interpret psychological stimuli" (Deikman, 1966); "decentering"– the capacity to view experience from "outside" (Safran & Segal 1990); and in traditional Buddhist meditation, the position of the "silent witness". This enlargement of awareness is not the same as dissociation or disconnection, but rather a functional development that enables the practitioner to transform previously rigid cognitive and emotional styles. Shapiro et al. (2006) identified further outcomes of reperceiving: values clarification, which provides an opportunity to choose new and more congruent values; and exposure, where previously difficult thoughts and emotions can be encountered so as to reduce their capacity for disruption.

2.4. Mindfulness-based interventions (MBIs)

Mindfulness-based interventions**,** therapeutic approaches grounded in mindfulness, promote the practice as an important part of good physical and mental health. In the Western world, mindfulness-based interventions are becoming widely accepted methods of addressing the symptoms associated with many commonly experienced mental health challenges and/or emotional concerns. Currently, there are four recognized therapy models that incorporate mindfulness practices: Mindfulness Based Stress Reduction

(MBSR; Kabat-Zinn, 1990), Mindfulness Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2002), Dialectical Behavior Therapy (DBT; Linehan Marsha, 1987) and Acceptance and Commitment Therapy (ACT, Hayes, Wilson, and Strosahl, 1999). Though these approaches all involve mindfulness techniques, there are slight differences between each modality. MBSR and MBCT actively teach mindfulness meditation, but MBCT also integrates cognitive behavioral therapy techniques as a part of treatment. DBT and ACT do not teach mindfulness mediation but instead utilize other mindfulness exercises to promote awareness and focus attention. Additionally, while MBSR and MBCT focus on the process of developing mindfulness as well as any associated thoughts, DBT and ACT focus primarily on the cognitions experienced during the state of mindfulness. MBSR program is designed as an 8-week course with one weekly meeting for 2.5 hours to develop mindfulness skills and talk about stress and coping. “Formal” home assignments (45 min/day) following CDs with guided meditation practices—as well as “informal” (15 min/day) assignments to be carried out during other, daily activities are given every week to support training outside the courses. An intensive retreat (7 hours) is held during the sixth week. The three most central exercises in MBSR are the body scan, the sitting meditation, and hatha yoga postures. During the body scan, participants are lying down with eyes closed, carefully observing areas of the body, just noticing how they feel moment by moment with a non-judgmental attitude. Instructions are open and generally without suggestions (e.g., “Notice how your legs are in this moment—whether they are heavy or light. Just notice how they are, and let it be okay”). Likewise, breathe exercises and hatha yoga train mindfulness in part through continued, non-judgmental noticing of bodily sensations. In sitting meditation, participants are encouraged to observe and be curious about their thoughts as they wander but crucially not to judge them as “good” or “bad.” Thus, an essential goal is a renewed relation to the total life experience, incorporating a non-judgmental attitude toward all things, beings, thoughts, and emotions. Awareness of the transiency of all things is aimed for to improve the central ability to “let go” of, for example, painful thoughts and emotions. This presumably reduces tendencies to ruminate and eases the non-judgmental returning of awareness to the present moment. MBCT program is conducted over a period of six weeks, and consisted of seven 2 hour group sessions, and an additional half day retreat at the end of the fifth week. During each session the instructor guide the participants through different meditations including breathing meditation, body scan, open awareness meditation, walking meditation and compassion meditation. Each session additionally included different awareness exercises, stories and group discussions to allow a broader understanding of mindfulness principles, and provide the participants with opportunities to share their meditation experiences. Daily home practice of formal meditation of at least 20 minutes is required, as well as informal daily mindfulness practice in which participants attend to regular daily activities in a mindful manner. Audio CD's with meditation instructions are provided to facilitate home practice. Additionally, participants received a daily email notification directing them to an online diary for filling a report of their daily home practice. During the half day retreat participants practice different formal meditations in silence, with no exercises or group discussions. DBT is a cognitive behavioral and mindfulness-based therapy for borderline personality disorder (BPD). The main dialectic is between the opposing forces of change and acceptance, i.e. accepting the ways things are while simultaneously working to improve them. Mindfulness is taught as a set of skills through structured exercises. These include observing, describing and participating in one's present moment experience in a non-judgmental, one-thing-at-a-time and effective manner. DBT teaches how to make use of the 'wise mind' – the inherent ability to be clearly aware of thoughts and feelings. Finally, ACT is an empirically based psychological intervention that uses acceptance and mindfulness strategies, together with commitment and behavior change strategies, to increase psychological flexibility. Psychological flexibility means fully connecting with the present moment as a conscious human being and, based on what the situation affords, changing or persisting in behavior depending on the individual's chosen values. Although it draws strongly on a cognitive behavioral framework, ACT differs in its predominant use of mindfulness exercises in individual therapy to assist people towards flexibility.

2.5. Mindfulness questionnaires, scales and assessments for measuring

Mindfulness can be considered both a *state* and a *trait* (Medvedev, Krägeloh, Narayanan, & Siegert, 2017). A state refers to a momentary emotional reaction to internal and/or external trigger(s) which also involves physical, behavioral, cognitive and psychological reactions. The duration and intensity of the emotion felt can vary due to various factors such as the level of arousal, frustration level, subjective perception, the context and etc. Once the emotional reaction passes, equilibrium resumes (Spielberger & Sydeman, 1994). States, hence, create a temporary emotional change. Emotional states presumably fluctuate over time. A trait, on the other hand, implies a more permanent presence and a stable level of emotion. Traits refer to the stable, consistent and enduring disposition of the individual (Allport & Odbert, 1936), which includes emotional reactions and temperament, rather than situational, variable and temporary factors (Hamaker, Nesselroade, & Molenaar, 2007). Traits present the tendency of an individual to constantly feel, think and behave in a certain way (Spielberger & Sydeman, 1994). One can speak of a trait when the same emotional states chronically appear in a stable frequent manner and it is generalized in many different situations and contexts (Forgays, Forgays, & Spielberger, 1997). We often use traits to describe individual's personality characteristics that are stable of time. The traits interact with different factors to create many emotional states. This is done by the manner in which the factors such as situations, stimuli and interactions are being perceived, processed and the psychological, behavioral and emotional outcome of these processes (Kantor, Endler, Heslegrave, Kocovski, 2001). The states/traits interactions cause the attention and information processing and the interpretational level to become very limited and biased (Block, 2005). Regarding mindfulness, *state mindfulness* refers to a temporary condition in which an individual is aware of their thoughts and feelings and able to stay present when distractions arise while *trait mindfulness* is the more permanent ability to enter a mindful perspective at will, in which an individual recognizes what they are thinking and feeling, accepts them without judgment, and keeps the focus on being present. The most popular scale for measuring mindfulness is the *Mindful Attention Awareness Scale* (MAAS), developed by Brown and Ryan (2003). The trait MAAS is a 15-item scale designed to assess a core characteristic of mindfulness, namely, a receptive state of mind in which attention, informed by a sensitive awareness of what is occurring in the present, simply observes what is taking place. The MAAS measures an individual's tendency to enter a state of mindfulness through the individual's frequency of having certain experiences related to mindfulness and mindlessness. The *Cognitive and Affective Mindfulness Scale* (CAMS) was first developed in 2005 by Kumar, Feldman, and Hayes. It was subsequently reviewed and revised in 2007 by Feldman, Hayes, Kumar, Greeson, and Laurenceau into the Cognitive and Affective Scale of Mindfulness-Revised (CAMS-R). The *Cognitive and Affective Mindfulness Scale* (CAMS) is an 18-item scale designed to capture a broad conceptualization of mindfulness, with language that is not specific to any particular type of meditation training. The Cognitive Affective Mindfulness Scale Revised (CAMS-R) is a 12 item, unidimensional scale that assesses the four domains of mindfulness (attention, present-focus, awareness, acceptance/non-judgment). The consensus on the

revised CAMS is that it effectively captures a multi-component measurement of mindfulness and can be relied upon to relate with other measures as expected. The *Freiburg Mindfulness Inventory* (FMI; Buchheld, Grossman, Walach, 2001) is a 30-item scale that is designed to measure the concept of mindfulness, measured as either an outcome of an intervention, as a moderating variable or personality trait. A 14-item short form version has also been developed, which is more suitable for use in generalized context where a Buddhist background of mindfulness is limited and measures mindfulness as a unidimensional construct (or one component on its own, without multiple subcomponents or facets). The *Langer Mindfulness Scale* (LMS; Pirson, Langer, Bodner, and Zilcha-Mano, 2012) is a 21 or 14-item scale that assesses mindfulness in four categories that include novelty producing, flexibility, novelty seeking, and engagement. These domains "describe a person's relative openness to experience, willingness to challenge strict categories, and continual reassessment of the environment and their reactions to it" (Langer, 2004). These researchers noticed that many mindfulness measures suffered from a lack of clarity or empirical support, and set out to create a more precise and structured assessment to capture a measure of mindfulness that incorporated a socio-cognitive perspective. The *Solloway Mindfulness Survey* (SMS) was created in 2007 by Solloway and Fisher, for the purpose of tracking the progress of mindfulness students as they learn about mindfulness and begin to engage in the practice. The SMS consists of 30 items that measures mindfulness from the perspective of mindfulness as a skill set or capacity to practice, a semi-state in that it is changeable, but more trait-like in that it is relatively stable unless knowledge and practice is actively pursued. Another mindfulness scale that comes from a skill-based perspective is the *Kentucky Inventory of Mindfulness Skills* (KIMS; Baer, Smith, & Allen, 2004). This scale was developed to measure four mindfulness related skills, as well as an overall tendency to be mindful during daily life. The KIMS consists of 39 items related to what one does while practicing mindfulness, and how one does it. The "what" skills include observing (noticing or attending to) current experience, describing (noting or labeling observed experiences) with words, and participating (focusing full attention on current activity); the "how" skills include being nonjudgmental (accepting, refraining from evaluation), being one-mindful (using undivided attention), and being effective (using skillful means) (Baer et al., 2009).
The *Philadelphia Mindfulness Scale* (PHLMS; Cardaciotto, Herbert, Forman, Moitra, and Farrow, 2008) is a 20-item measure consisting of 2 sub-scales (acceptance and present moment awareness). Some research has suggested that these two components are strong

and independent factors of mindfulness, and thus should be considered two components for the purpose of measuring mindfulness. The *Toronto Mindfulness Scale* (TMS; Lau et al., 2006) is a 13-item, two-factor structure (Curiosity, Decentering), uniquely state-oriented for use immediately following a meditation experience and has been validated in a number of clinical contexts. The items of Factor 1 (Curiosity) reflect an attitude of wanting to learn more about one's experiences. The items of Factor 2 (Decentering) reflect a shift from identifying personally with thoughts and feelings to relating to one's experience in a wider field of awareness. The *Southampton Mindfulness Questionnaire* (SMQ; first introduced as *Mindfulness Questionnaire*, MQ, Chadwick et al. 2005, in Baer et al. 2006) is a 16-item scale with four related bipolar aspects of a mindful approach to distressing thoughts and images. Hence, the SMQ may prove to be very useful for the investigation of relationships between mental health problems and mindful awareness. The scale appears particularly suited for studies focusing on the effects of a mindful attitude towards distressing inner experiences but may be too specific for more general use, as it does not involve items relating to positive or neutral phenomena. Yet, the current situation in the self-report assessment of mindfulness suffers from several limitations. First, each of the validated mindfulness scales is associated with particular advantages but also disadvantages for a comprehensive assessment of mindfulness in the general population. Second, substantial differences in the covered aspects of mindfulness hinder the comparison of results from studies using different scales, thus impeding communication about the construct (Brown et al., 2007; Malinowski, 2008). Finally, results from current scales point at a possible further problem: the inclusion of items that can be easily misinterpreted, in particular by respondents who are not familiar with the mindfulness concept (cf. Grossman, 2008). The following questionnaire was the assessment used in the present work and one of the most popular measure of mindfulness in different contexts.

2.5.1. The Five Facet Mindfulness Questionnaire

The *Five Facet Mindfulness Questionnaire* (FFMQ; Baer et al., 2006) is a 39-item self-report measure of mindfulness skills that is becoming widely used in psychological research generally and in process-outcome work on MBCT and MBSR specifically. This scale and its facets resulted from an exploratory factor analysis of the combined pool of 112 items collected from the KIMS, the FMI, the MAAS, the CAMS, and the SMQ. Although the items of the FFMQ were compiled from five separate mindfulness measures, 24 of its 39 items are from the KIMS and four of the five facets correspond to the four facets that comprise the KIMS. The factor analysis produced five factors that could be replicated with confirmatory factor analysis (Baer et al., 2006). The five facets the authors refer to can be described as follows:

- *Observing* facet measures the tendency to notice or attend to internal and external experiences, such as sensations, emotions, cognitions, sounds, sights, and smells (items such as “I remain present with sensations and feelings even when they are unpleasant or painful”).
- *Describing* measures the tendency to describe and label these experiences with words (items such as “I'm good at finding the words to describe my feelings”).
- *Acting with awareness* facet refers to bringing full awareness and undivided attention to current activity or experiences (items such as “I find it difficult to stay focused on what's happening in the present”).
- *Nonjudging* refers to a nonevaluative stance toward inner experiences (items such as “I tend to evaluate whether my perceptions are right or wrong”).
- *Nonreactivity* measures the tendency to allow thoughts and feelings to come and go, without getting caught up in them or carried away by them (items such as “Usually when I have distressing thoughts or images, I step back and am aware of the thought or image without getting taken over by it”).

Items were scored on a five-point Likert scale ranging from 1 (never or very rarely true) to 5 (very often or always true). Facet scores were computed by summing the scores on the individual items. Facet scores range from 8 to 40 (except for the nonreactivity facet which ranges from 7 to 35), with higher scores indicating more mindfulness. Preliminary psychometric analyses show that the FFMQ has adequate reliability, convergent and discriminant validity, and incremental validity in the prediction of psychological symptoms (Baer et al., 2006). The five facet scales demonstrated adequate to good internal consistency, with alpha coefficients ranging from .75 to .91, and relationships between the facet scales and other variables were consistent with predictions in most cases.

2.6. Neuroscience of mindfulness

Given the increasing popularity of mindfulness meditation, and mounting evidence that meditation has wide-ranging and measurable effects on many aspects of health, neuroscientists too are becoming interested in understanding the biological mechanisms that underlie these effects in the brain. Farb et al., (2007) broke new ground in our understanding of mindfulness from a neuroscience perspective. They argued that people interact with the world using two different set of networks: one network for experiencing your experience involves what is called the "default network", which includes regions of the medial prefrontal cortex, along with memory regions such as the hippocampus; one network of direct experience that includes the insula, a region that relates to perceiving bodily sensations and the anterior cingulate cortex which is a region central to switching your attention. The default network is involved in planning, daydreaming and ruminating. When the default network is active you take in information from the outside world, process it through a filter of what everything means, add your interpretations and doesn't take much effort to operate. On the contrary, when the direct experience network is active you are experiencing information coming into your senses in real time. A series of other studies has found that these two circuits, ‘narrative’ and direct experience, are inversely correlated. You can experience the world through your narrative circuitry, which will be useful for planning, goal setting, and strategizing. You can also experience the world more directly, which enables more sensory information to be perceived. Experiencing the world through the direct experience network allows you to get closer to the reality of any event. You perceive more information about events occurring around you, as well as more accurate information about these events. Noticing more real-time information makes you more flexible in how you respond to the world. You also become less imprisoned by the past, your habits, expectations or assumptions, and more able to respond to events as they unfold. Tang et al., (2015) wrote an extensive review that took look at the current state of neuroscience research on mindfulness meditation. The authors wrote: “Although meditation research is still in its infancy, a number of studies have investigated changes in brain activation at rest and during specific tasks that are associated with the practice of, or that follow, training in mindfulness meditation. There is emerging evidence that mindfulness meditation might cause neuroplastic changes in the structure and function of brain regions involved in regulation of attention, emotion and self-awareness”. Numerous neuroimaging studies have investigated changes in brain morphology related to mindfulness meditation. The study of Tang et al. found that eight brain regions were consistently altered in the experienced meditators: *anterior cingulate cortex* and *mid-cingulate cortex*, cortical regions involved in self-regulation, emotional regulation, attention, and self-control; *hippocampus*, subcortical structures involved in memory formation and facilitating emotional responses; *rostrolateral prefrontal cortex*, a region associated with meta-awareness (awareness of how you think), introspection, and processing of complex, abstract information; *sensory cortices* and *insular cortex*, the main cortical hubs for processing of tactile information such touch, pain, conscious proprioception, and body awareness and *superior longitudinal fasciculus* and *corpus callosum*, subcortical white matter tracts that communicate within and between brain hemispheres. Data were from studies that used different neuroimaging measurements but changes were seen in grey matter density of brain tissue (Vestergaard-Poulsen et al., 2009; Hölzel et al., 2011), thickness of brain tissue (indicating greater number of neurons, glia, or fibers in a given region) (Lazar et al., 2005; Farb et al., 2013), cortical surface area, and white matter fiber density. Tang et al., suggested in their review that the effects of meditation might involve large-scale brain networks and multiple aspects of brain function. Brain imaging studies not only reveal difference in brain structure but also changes in brain activation patterns. In their review, Tang et al. also investigated whether mindfulness meditation exerts its effects via altered activation of brain regions involved with attention, emotional regulation and self-awareness. Several functional and structural MRI studies on mindfulness training have investigated neuroplasticity in brain regions supporting attention regulation. The brain region to which the effects of mindfulness training on attention is most consistently linked is the anterior cingulate cortex (ACC). The ACC enables executive attention and control by detecting the presence of conflicts emerging from incompatible streams of information processing. Other attention-related brain regions in which functional changes have been observed following mindfulness meditation include the dorsolateral prefrontal cortex (PFC), where responses were enhanced during executive processing, and parietal attention regions, which showed greater activation following an MBSR course in people with social anxiety. One hypothesis driving emotion regulation is that mindfulness meditation strengthens prefrontal higher order cognitive (thinking) processes that in turn modulate activity in brain regions relevant to emotion processing, such as the amygdala. A number of brain-imaging studies appeared to support this hypothesis. Studies of mindfulness meditators have shown training to be associated with more positive self-representation, higher self-esteem, and higher acceptance of oneself. Such concepts are not easy to capture in neuroscientific studies. However, multiple studies show the insular is strongly activated during meditation. This is thought to represent amplified awareness of the present moment experience (Figure 1). Despite the enthusiastic reporting of positive findings on the effects of meditation on the brain, it should be pointed out that mindfulness meditation research is a young field, and many studies are yet to be replicated. They concluded: ‘if supported by rigorous research studies, the practice of mindfulness meditation might be promising for the treatment of clinical disorders and might facilitate the cultivation of a healthy mind and increased well-being’.

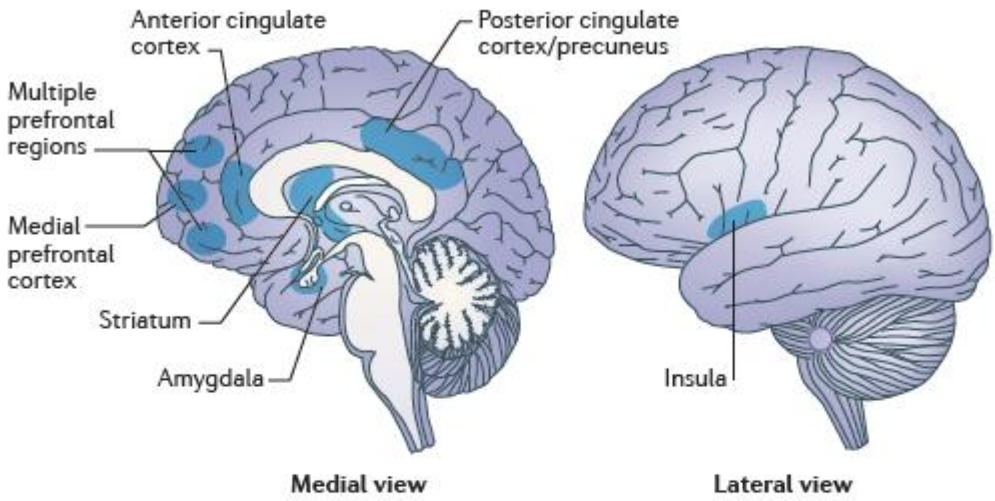

Figure 2.1 Brain regions involved in the components of mindfulness meditation (Tang et al., 2015)

Chapter 3

Experiment 1

1. Introduction

As mindfulness has been described as “a particular way to pay attention” (Kabat-Zinn, 1990, 2003), its effects could be modify our attentional processing. More specifically, recent conceptualizations have suggested mindfulness meditation to improve self-regulation of attention (Bishop et al., 2004; Shapiro et al., 2006). Mindfulness aims to achieve a relaxed, non-judgmental awareness of your thoughts, feelings and sensations: “a direct knowing of what is going on inside and outside ourselves, moment by moment” (Williams et al., 2002). Buddhist monks have been practicing a similar technique for 2,500 years, but western medicine caught on in the late 1970s when a US medical professor, Jon Kabat-Zinn, began successfully treating patients with chronic pain using a secular program he called Mindfulness-Based Stress Reduction (see Chapter 2 for more details). It has been found to be effective in the management of stress, physical illnesses and psychological difficulties with a range of clinical and non-clinical populations (Grossman et al., 2004). So far, few studies investigated the effect of MBSR training on attentional performance. In a pioneer study, Jha, Krompinger, and Baime (2007) examined the effects of mindfulness practice on the three attention networks (alerting, orienting, and conflict monitoring) using the Attention Network Test (ANT; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Attentional efficiency was assessed before and after an eight-week MBSR course administered to meditation-naïve participants, a one-month intensive mindfulness retreat attended by experienced meditators, and an eight-week no treatment control group. Results of the study indicate that the retreat group showed better conflict monitoring at baseline than participants in the control and MBSR groups, suggesting that executive attention improves with long-term exposure to mindfulness meditation. An interesting finding was that orienting scores improved in the MBSR group to levels that were higher than those displayed by either the control or retreat participants. This is surprising because one would expect orienting scores to increase in both meditation groups. Finally, the retreat group displayed improved alerting compared to control and MBSR groups. The authors concluded that mindfulness training may enhance the functioning of each of the attentional subsystems at various points in the course of mindfulness training. van den Hurk et al., (2010) used the attention network test and tested a group of more experienced meditators than those tested in the study by Jha et al. (mean 14.5 years, range 0.33–35 years in our group vs. mean 5 years, range 0.33–30 years in the study by Jha et al.). With this sample of more experienced meditators, they expected to increase the likelihood of finding differences within the orienting and executive network. They found that meditators showed a significant better orienting of attention and a trend towards a significantly better executive attention and that meditators showed a significantly higher degree of attentional processing efficiency than controls. Tang et al. (2007) also reported noteworthy findings from a study of undergraduate Chinese students randomly assigned to 5 days of 20-minute meditation practice with the integrative body–mind training (IBMT) or a control group given training in Progressive Muscle Relaxation (PMR) on the ANT. IBMT comes from traditional Chinese medicine and incorporates aspects of other meditation training, such as body relaxation, breathing adjustment, and mental imagery in addition to mindfulness training. Compared with the control group, the experimental group showed greater improvement in conflict scores on the ANT. While this study provides valuable data about the impact of relatively brief meditation training on attentional performance compared to a relaxation control group, the intervention was not strict mindfulness training, as noted above. Mindfulness training is a feasible intervention and may improve behavioral and neurocognitive impairments (Zylowska et al., 2008). The main goal of this study is to investigate attention improvements of MBSR training compared to a Control group using the Attention Network Test for Interaction-Vigilance (ANTI-V; Roca et al., 2011), to better understand awareness strategies used by our attentional system.

2. Method

2.1. Participants

Forty-four participants took part in this study (range 22-61 years old with a mean of 38.44) recruited from those who were interested in learning meditation and who had no prior meditation experience. Participants were assigned to a MBSR intervention group (21 participants) and to a waiting list group (23 participants) both matched in age and gender. All participants had a normal or corrected-to-normal vision.

2.2. Interventions

2.2.1 MBSR (Mindfulness-based stress reduction protocol)

MBSR is an 8 week intervention protocol (see Chapter 2 for more details) that consists of multiple forms of mindfulness practice, including formal and informal meditation practice, as well as hatha yoga (Kabat-Zinn, 1990). The formal practice consists of breath-focused attention, body scan-based attention to the transient nature of sensory experience, shifting attention across sensory modalities, open monitoring of moment-to-moment experience, walking meditation, and eating meditation. Informal practice entails brief pauses involving volitionally shifting attention to present moment awareness. Together, this package of mindfulness practices aims to enhance the ability to observe the immediate content of experience, specifically, the transient nature of thoughts, emotion and physical sensation. MBSR training was conducted by a teacher with experience in teaching mindfulness meditation.

2.3. Materials and procedure

All participants were tested individually in a quiet room after signing a consent form and completing the Italian version of Five Facets of Mindfulness Questionnaire (FFMQ, Baer et al., 2006; Giovannini et al., 2014).

2.3.1. Attention Network Test for Interactions-Vigilance (ANTI-V)

We used a modified version of ANTI-V (Roca et al., 2011; Bukowski et al., 2015; Morales et al., 2015). The only change with respect to the original task is that the latter used arrows as stimuli instead of cars (Figure 1). Participants were presented with a black fixation cross for a range of 400-1600 ms, that varied randomly, followed by a row of five arrows (above or below the fixation cross) pointing either left or right (200 ms), containing the central target arrow. The task was to indicate the direction of the central arrow, independently of the direction of flankers, by pressing “c” for left or “m” for right and the participants’ responses were allowed up to 2000 ms. In order to analyze the functioning of executive control network, half of the times flanker arrows pointed at the same direction of central target arrow (congruent condition), whereas they pointed in the opposite direction (incongruent condition) in the other half of trials. Before presentation of the stimuli (100 ms) an asterisk was presented (50 ms) either in the same location of target (valid cue condition), in the opposite location of target (invalid cue condition) or no asterisk presentation (no cue condition). Also, half of trials presented a warning tone

(50 ms) after stimulus (warning tone condition) and half of trials did not present a warning tone (no warning tone condition). Finally, in order to analyze the functioning of vigilance, a 25% of trials presented a significantly displaced central target arrow and participants had to detect these infrequent stimuli by pressing a spacebar. The task was composed of 7 blocks of 64 trials each (48 trials for ANTI, 16 for vigilance). The first block was a practice block and participants received feedback of their accuracy. The last 6 blocks were experimental blocks and no accuracy feedback was given. The task had a duration of about 40 min.

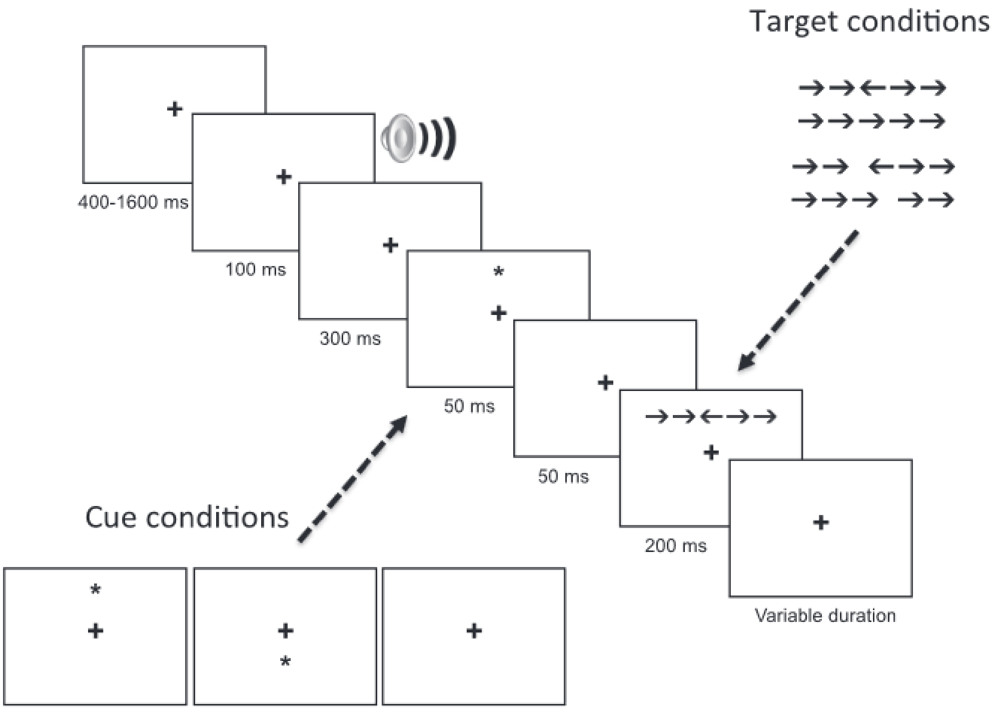

Figure 1. Attentional Network Task for Interaction-Vigilance. Schematic representation of the procedure (Bukowski et al., 2015)

2.4. Data analysis and results

First, analyses were run in 2 steps: ANTI analysis and Vigilance analysis. In order to analyze the attentional effects of ANTI task, RT and Accuracy (Errors %) data were submitted to ANOVAs with Warning signal (No Tone and Tone), Visual Cue (Invalid, No-cue and Valid) and Congruency conditions (Incongruent and congruent) as repeated-measures factor. Attention network scores were computed as subtraction of specific conditions (phasic alertness score: No Tone – Tone, only in No-cue condition; orienting score: Invalid – Valid and executive control score: Incongruent – Congruent). Further, to evaluate performance in the Executive Vigilance (EV) task the Signal Detection Theory (SDT) indexes were calculated: Hits as a proportion of correct responses to infrequent stimuli; False Alarms (FA) as a proportion of incorrect responses to frequent targets; sensitivity (d') and response bias (β, Beta). Then, we carried out an ANOVA, on the pre-treatment session (PRE), with Group as a between participants variable, and Warning Signal, Visual Cue and Congruency as within participants variables, to see whether the task worked properly and there were no group differences. Here, we observed main effects of the three ANTI variables. For RT results, Warning Signal [$F(1, 43) = 13{,}801$, $p < .001$], Visual Cue [$F(2, 86) = 42{,}417$, $p < .001$] and Congruency [$F(1, 43) = 157{,}45$, $p < .001$]. For Accuracy (Errors %) results, Warning Signal [$F(1, 43) = {,}25840$, $p > .05$], Visual Cue [$F(2, 86) = {,}71185$, $p > .05$] and Congruency [$F(1, 43) = 50{,}593$, $p < .001$] (Figure 2). However, none of this effects was modulated by Group, neither was a main effect of Group [$F(1, 42) = {,}10635$, $p > .05$]. Therefore, the task seemed to work properly and the groups were similar. For EV results, a significant main effect of blocks was observed for Hits [$F(5, 215) = 3{,}3451$, $p < .005$] but no for FAs [$F(5, 215) = {,}74436$, $p > .05$]. Figure 3 shows that Hits tend to increase with time on task. No significant main effect of blocks was found for Response Bias (β) [$F(5, 215) = 1{,}1814$, $p > .05$] and a significant trend was found for Sensitivity (d') [$F(5, 215) = 2{,}0504$, $p = .07$] (Figure 4). Further, repeated measures ANOVA for Session (PRE-POST) x Group x Warning Signal, Session (PRE-POST) x Group x Visual Cue and Session (PRE-POST) x Group x Congruency were not significant. No significant differences found in Executive Vigilance indexes neither. Then, an analysis was performed for each FFMQ factor to see whether training was effective. Session and Group were introduced in a mixed ANOVA for each factor. Only the Observe measure showed a significant interaction, indicating that the MBSR group increased the Observe score in the post-treatment session more than the control group. That is, increased Observe score was significant only for MBSR group (effect of training), [$F(1, 42) = 10{,}79202$, $p < .005$] (Figure 5). No change in the Control group, $F(1, 42) = {,}012131$, $p = .91$. Further, a Bayes factor analysis on the same data showed that the Bayes factor for the interaction term is 7.474. A Bayes factor of this size indicates strong evidence of this effect (Figure 6).

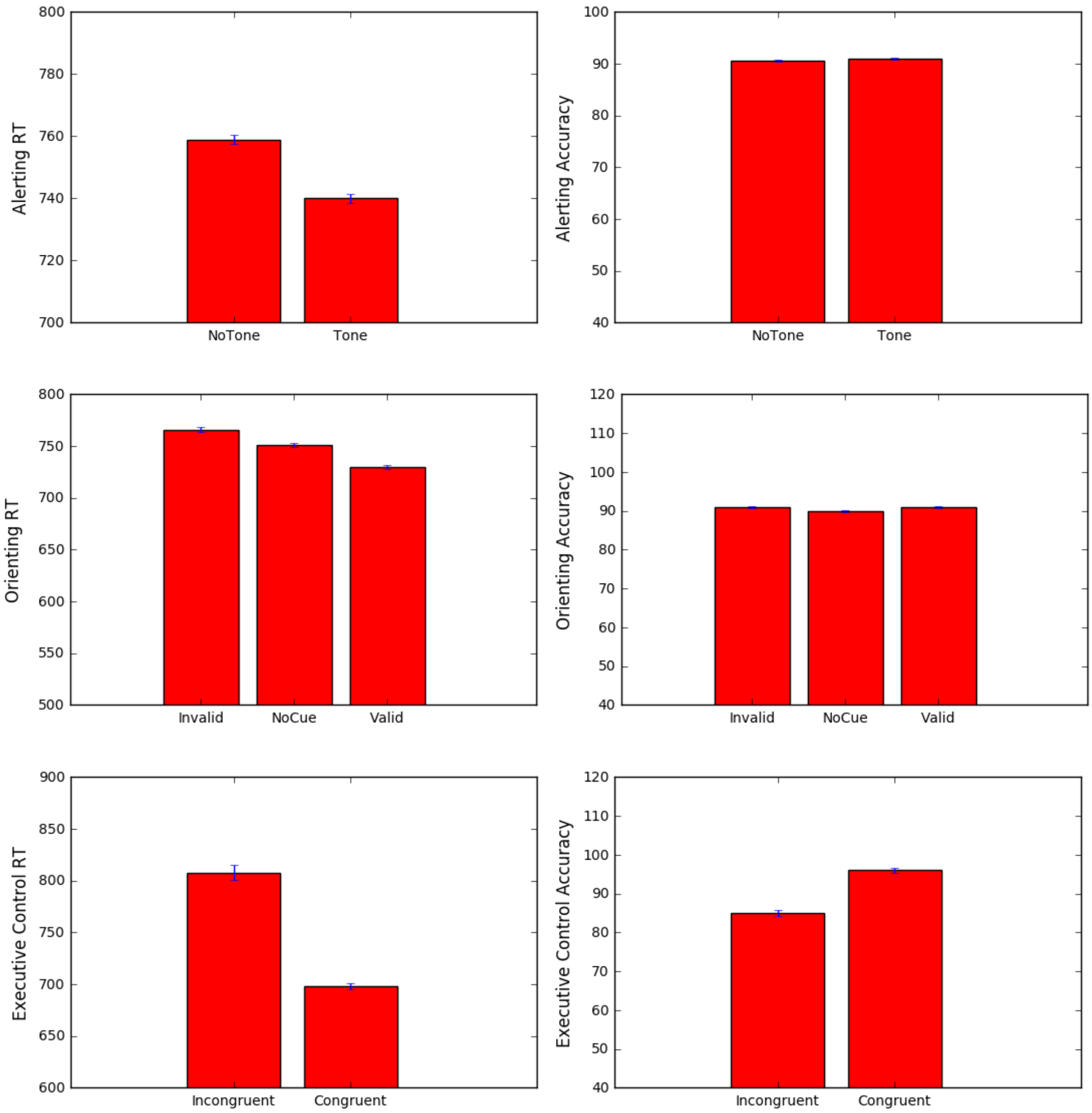

Figure 2. RT mean and Accuracy (%) of the three attentional networks

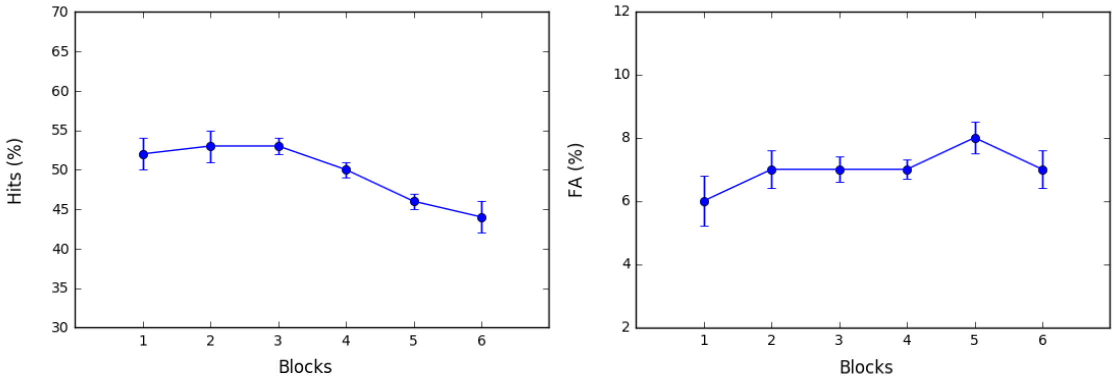

Figure 3. Executive Vigilance performance per blocks in ANTI-V task: Hits and FA

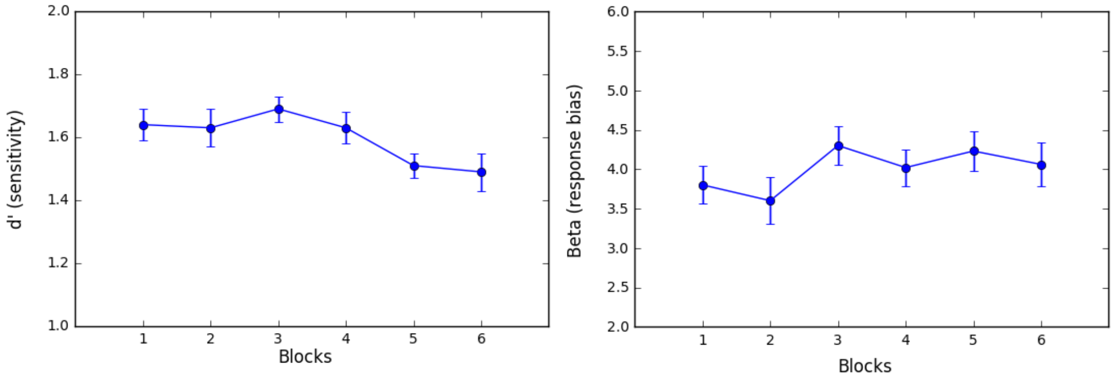

Figure 4. Executive Vigilance performance per blocks in ANTI-V task: d' and Beta

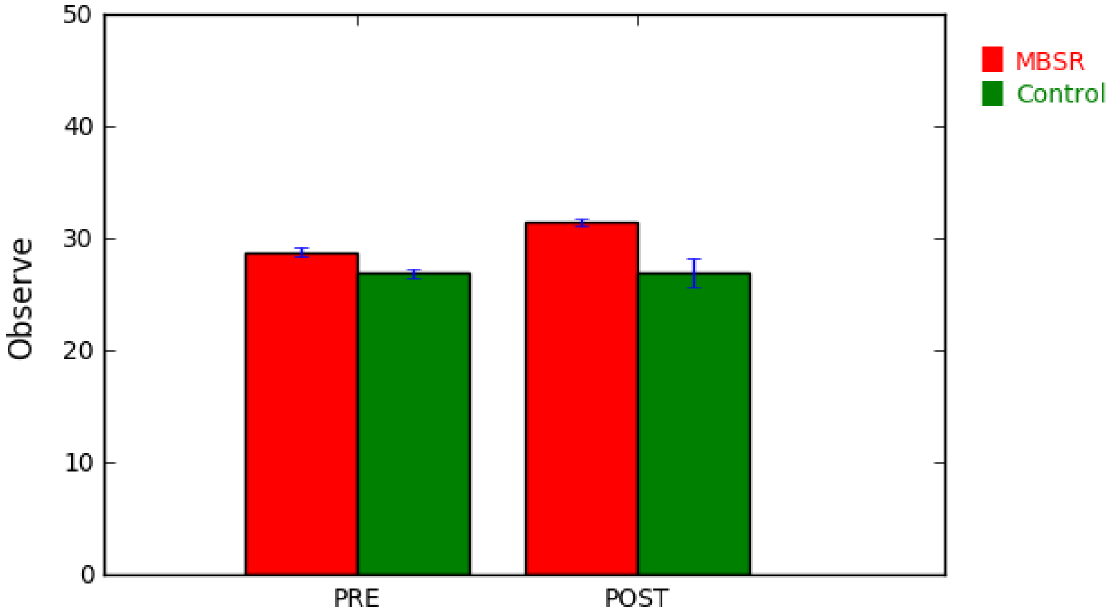

Figure 5. Significant increased Observe score in posttreatment session only for MBSR group (effect of training)

Model Comparison - S2_Observe

Models	P(M)	P(M|data)	BF $_M$	BF $_{10}$	% error
Null model	0.500	0.118	0.134	1.000	
S1_Group	0.500	0.882	7.474	7.474	7.391e -4

Figure 6. Bayesian analysis (JASP) of the Observe score difference (marked number) in posttreatment session: MBSR and Control group

3. Discussion

The main goal of this study was to investigate whether a mindfulness training could affect attentional performance. More specifically, whether MBSR training could have its effects on attentional networks (Alerting, Orienting and Executive Control) and vigilance performance. In the present study, Attention Network Test for Interactions-Vigilance (ANTI-V) was used to investigate these effects. A further variation of the ANTI in which a measure of vigilance is added. This measure evaluates tonic alertness (i.e., the ability to detect infrequent, unpredictable and unexpected stimuli) and it is obtained in addition to the usual phasic alertness, orienting and executive control scores. This new task provided a direct measure of vigilance. Participants receiving MBSR experience performed ANTI-V task before and after training. At the same time, their performance was contrasted with the performance of control participants who were tested also in two sessions. Data analysis revealed no significant differences in MBSR group respect to Control group in all the measured attentional indexes: ANTI and EV measurements. However, the effect of training was effective. Participants in the MBSR group show an increased Observe score in the posttreatment session (effect of training). No significant differences in the Control group. MBSR is aimed to increase awareness of the present moment. The treatment plan is a new and personal way to deal with stress to the individual. External stressors are part of life and cannot be changed, but coping skills and how to respond to the stress can be changed (Bakhshani et al., 2010). In addition, few studies report effects of MBSR training in improving cognitive functions as attentional performance. Many future studies are needed to develop a better understanding of the relationship between MBSR training and attention. Future studies should include an active-control group, neuroimaging measurements together with behavioral measures and more elaborated characterization and control over training protocols (Jha et al., 2007). Although finding significant increases in a measure attention, MBSR training may not have been sufficient to demonstrate lasting effects of mindfulness on components of attention. Further, studies reported improvements of cognitive functions mostly when the experimental group was formed by expert meditators. Affective, cognitive, physiological, and behavioral changes resulting from long-term mindfulness practices are likely to differ from short-term effects (Semple et al., 2010). Finally, evaluating the effects of mindfulness meditation practices over time would enlarge our understanding of meditation as attention training. Comparing selected indexes of attention in mindfulness expert meditators with varying levels of experience might also expand our understanding of this relationship.

Experiment 2

1. Introduction

Mindfulness could be described as “an intentional cultivation of a non-judmental moment-to-moment awareness” (Kabat-Zinn, 1990). Moreover, it is characterize by auto-regulation of attention and the adoption of a particular orientation to present moment experience (Bishop et al., 2002). Further, mindfulness meditation involves a broader observation of one’s present moment experience, that is, physical sensations, thoughts and feelings (Baer, 2003). Recent enthusiasm for mindfulness in psychology has resulted in proliferation of self-report inventories that purport to measure mindful awareness as a trait (Grossman et al., 2011). These measures are a useful way to examine the mediational mechanisms and outcomes of mindfulness-based therapies (Brown et al., 2011), even if there is some criticism from experts in the field regarding their use (Grossman, 2011). One of the most popular mindfulness questionnaire is the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) (see Chapter 2 for more details). Over the last decade, the psychometric properties of the FFMQ have been extensively examined in populations from different countries (Bohlmeijer et al., 2011; Deng et al., 2011; Heeren et al., 2011; Lilja et al., 2011; Cebolla et al., 2012; Sugiura et al., 2012; Dundas et al., 2013; Giovannini et al., 2014). A few studies investigated the relationship between FFMQ and attentional skills. Di Francesco et al., (2016) found some interesting correlations between the two facets of FFMQ (*Observe* and *Acting with awareness*) and the attentional performance using ANTI task. Further, they found that regression analysis revealed that the mindfulness facets Observe and Acting with awareness were effective predictors of the efficiency of the three assessed attentional networks. More specifically, they found that that Observe scores predicted higher Alerting scores. Instead, Acting with awareness was a predictor of Orienting network. Moreover, they found no significant interactions between the two facets and Executive Control network. As suggested by Di Francesco et al., (2016), the aim of this study is to assess the relationship between mindfulness facets of FFMQ and the Attention Network Test for Interactions-Vigilance (ANTI-V; Roca et al. 2011), that includes a direct measure of executive vigilance (see Chapter 3, Experiment 1, for more details). The new measure included may change the interactions between the two mindfulness facets and the attentional performance as participants have to pay attention to both the main task (responding accordingly to the central arrow direction) and to the vigilance task (reporting trials in which the central arrow is moved slightly on the left or on the right).

2. Method

2.1. Participants

Seventy-six participants took part in this study (range 19-35 years old with a mean of 24.97) from Sapienza University of Rome for extra class credit. All participants had normal or corrected-to-normal vision and reported no clinical history of psychological or neurological problems.

2.2. Assessment

The Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) is a self-report measure assessing a general tendency to be mindful. This scale is composed of 39 items that are divided into five subscales or facets: observing, describing, acting with awareness, non-judging, and non-reactivity of experience. The *Observing* facet measures the tendency to notice or attend to internal and external experiences, such as sensations, emotions, cognitions, sounds, sights, and smells. Example items are "I remain present with sensations and feelings even when they are unpleasant or painful" and "I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing." *Describing* measures the tendency to describe and label these experiences with words. Items include "I'm good at finding the words to describe my feelings" and "My natural tendency is to put my experiences into words." The *Acting with awareness* facet refers to bringing full awareness and undivided attention to current activity or experiences. Example items are "I rush through activities without being really attentive to them" and "I find it difficult to stay focused on what's happening in the present." *Non-judging* refers to a non-evaluative stance toward inner experiences. Items include "I tend to evaluate whether my perceptions are right or wrong" and "I think some of my emotions are bad or inappropriate and I shouldn't feel them." *Non-reactivity* measures the tendency to allow thoughts and feelings to come and go, without getting caught up in them or carried away by them. Items include "Usually when I have distressing thoughts or images, I step back and am aware of the thought or image without getting taken over by it." The subscales include eight items, except the non-reactivity scale, which is composed of seven items. Each subscale is a Likert scale ranging from 1 (never or very rarely true) to 5 (very often or always true).

2.3. Materials and procedure

Materials and procedure were identical to Experiment 1.

2.4. Data analysis and results

First, in our results we replicated all the main previous findings with the ANTI-V task (Roca et al., 2011). These main effects of attentional indexes are not reported here, as they fall beyond the aim of the present study. Then, we computed the correlations between two mindfulness facets considered on attentional networks, Observe and Acting with awareness and the ANTI-V scores: both RT and Accuracy scores and Executive Vigilance performance indexes. Additionally, we conducted a series of multiple regression analyses, with the ANTI-V scores as dependent variables and the FFMQ facets scores as predictors like suggested by Di Francesco et al., (2016). For Observe, the first analysis revealed no significant correlations with the ANTI-V scores while for Acting with awareness we found a significant negative correlation only with Orienting Accuracy, $r = -0.26$, $p < .05$. All other correlation analyses of ANTI scores were not significant (Table 1). Correlation analyses between vigilance performance indexes with FFMQ facets were not significant and not reported in Table 1. As reported in Table 2, we found a corresponding pattern of results for the regression analyses. The regression revealed that Observe significantly predicted the dependent variable Orienting Accuracy, $\beta = -.33$, $p < .05$. Moreover, Acting with awareness is also a predictor of Orienting Accuracy, $\beta = .30$, $p < .05$. All other regression analyses were not significant and not reported in Table 2.

Table 1. Correlation results

	Alerting RT	**Orienting RT**	**Executive Control RT**
Observe	-0.08	0.01	-0.04
Acting with awareness	-0.02	-0.09	-0.17
	Alerting Accuracy	**Orienting Accuracy**	**Executive Control Accuracy**
Observe	0.16	-0.19	-0.12
Acting with awareness	-0.10	-0.26**	-0.12

**p < .05

Table 2. Multiple regression results

Dependent variable	*R*	*R*^{2}	*Adjusted R*^{2}	*F*	*Predictor*	*β*	*t*
Orienting Accuracy	.19	.03	.02	2.79**	*Observe*	-.25	-2.31**
Orienting Accuracy	.26	.06	.05	5.43**	*Acting with awareness*	-.31	-2.83**

**p < .05

3. Discussion

The aim of this study was to investigate whether and how self-reported dispositional mindfulness facets are predictive of attentional network performance in a population naïve to meditation. To this end, we used the FFMQ questionnaire (Baer et al. 2006) to assess mindfulness facets and the ANTI-V test (Roca et al., 2011) to assess the efficiency of attentional networks and vigilance performance. Observe facet interaction with Alerting score found in Di Francesco et al., (2016) was not found using ANTI-V task. Observe facet measures the tendency to notice or attend to internal and external experiences, such as sensations, emotions, cognitions, sounds, sights, and smells. The ANTI-V task, because of its difficulty (i.e., executive vigilance trials together with attentional networks trials), may involve a more deeply attentional performance. As a consequence, external stimuli (i.e., warning signal) did not affect participants' Observe facet. Furthermore, we found that Acting with awareness facet was a negative predictor of Orienting Network as found in Di Francesco et al., (2016). Acting with awareness facet refers to bringing full awareness and undivided attention to current activity or experiences. Participants were focused on the central location avoiding the tendency to proceed in "automatic pilot" (Baer et al. 2004). This evidence suggests that individuals with higher Acting with awareness scores tend to be slower in reacting and less accurate when a stimulus is presented because of their involvement in the task. More generally, the two considered FFMQ facets seem to affect in a different way the performance of ANTI respect to that of ANTI-V. This difference could be seen in terms of a changed mind-set of a task respect to the other one. Further studies could better understand whether and how a different task (i.e., ANTI-Vea task), including two different measures of vigilance performance (executive and arousal components) together with the measure of the typical attentional networks (phasic alertness, orienting and executive control), may interact with dispositional mindfulness facets.

Chapter 4

Experiment 3

1. Introduction

The whole idea of science is to find regularities in our complex observations of the world, to uncover lawfulness in the chaos. The replication of important findings by multiple independent investigators is fundamental to the accumulation of scientific evidence. In Pashler et al., (2012), authors argue that "the frequency with which errors appear in the psychological literature is not presently known, but a number of facts suggest it might be disturbingly high". For this reason, the main goal of this experiment is to replicate results from Luna et al., (*In preparation*). The authors designed a task (Attention Network Test for Interactions and Vigilance - executive and arousal components (ANTI-Vea) that could measure simultaneously the functioning of the typical attentional networks (phasic alertness, orienting and executive control), together with two different components of vigilance (executive –detection of infrequent signals-, and arousal –immediate reaction without response control-). Hence, it could be possible to dissociate the vigilance decrement observed for arousal vigilance (i.e., increased mean and/or variability in RT over time on task) from the vigilance decrement observed for the executive vigilance (i.e., reduced detection of infrequent targets with time on task). Further, this new task could solve the problems observed with the previous attempt to measure the executive vigilance performance together with the three attentional networks seen in previous studies (ANTI-V; Roca et al., 2011; Bukowski et al., 2015; Morales et al., 2015; Roca et al., 2012; Roca et al., 2013). In the present study, we used the vertical version of the task, in which the target was infrequently displaced vertically, that could be more suitable to observe the vigilance decrement phenomenon in executive vigilance (i.e., changes in performance across time on task), which was not observed with the previous version of the task. The discussion about whether the decrement in executive vigilance could be due either to a reduced sensitivity or to changes in response bias across time is long-standing. In Thomson et al., (2016), authors show that the vigilance decrement would more likely be an increase in the response bias towards a more conservative criteria across time on task, rather than due to a sensitivity loss. Further, we also expected increases in both mean, variability measures of reaction time and lapses percentage in arousal vigilance across time on task. Finally, as in the study of Luna and collaborators, the inclusion of the arousal vigilance measure (in comparison with the previous ANTI-V version) would not have some relevant implications relating to the measurement of the three attentional networks functions.

2. Method

2.1. Participants

Eighty participants took part in this study (range 18-35 years old with a mean of 19.11) from University of Granada for extra class credit. Participants were recruited voluntarily. All participants had normal or corrected-to-normal vision and reported no clinical history of psychological or neurological problems.

2.2. Procedure and design

All participants were tested individually in a quiet room after signing a consent form.

2.2.1. Attention Network Test for Interactions and Vigilance - executive and arousal components (ANTI-Vea)

Participants were tested in a new version of the ANT task, named Attentional Networks Test for Interactions and Vigilance - executive and arousal components (ANTI-Vea). This new task was designed to obtain two different measures of vigilance components in addition to the classical measures of the three attentional networks (alerting, orienting and executive control networks). Hence, in the ANTI-Vea design we can distinguish three different types of trials: ANTI (a flanker task, assessing the functioning of phasic alertness, orienting, executive control, and their interactions), executive vigilance (EV, detection of infrequent signals), and arousal vigilance (AV, immediate reaction without response control). A fixation cross appeared at the center of the screen for a random time between 400 and 1600 ms. In ANTI and EV trials, the fixation cross remained on the screen for the whole duration of trial whereas in the AV trials the fixation cross remained on the screen for 500 ms. Finally, all trials finished with the fixation point until total trial time achieved 4100 ms as a consequence participants were uncertain about the starting of next trial. In ANTI trials (60% of the trials), above or below the fixation cross was presented a row of five arrows. Participants had to indicate the direction of central arrow ignoring the flanking ones by pressing on the keyboard letter "C" for left and "M" for right. The row of arrows was presented for 200 ms, and the participants' responses were allowed up to 2000 ms. In order to measure the executive control network, in half of trials the central arrow pointed in the same direction of flankers (congruent condition) whereas in other half of trials the central arrow pointed in the opposite direction of flankers (incongruent condition). To analyze the functioning of the orienting network, a spatially non-predictive visual cue (a black asterisk for 50 ms) preceded the row of arrows 100 ms before its appearance. The visual cue could be presented in the same location of the row of arrows (valid cue condition, 1/3 times), in the opposite location (invalid cue condition, 1/3 times), or it could be not presented (no cue condition, 1/3 times). Finally, to have a direct measure of phasic alertness network, a 50 ms warning auditory tone was presented in half of the trials for 500 ms before the row of arrows (tone condition) whereas in the other half of trials it was not presented at all (no tone condition). EV trials (20% of trials) had the same design as ANTI trials except that the central arrow, in the row of arrows, was vertically (either above or below) displaced from the center. Participants had to detect these infrequent stimuli, ignoring the direction of the central arrow, by pressing "space bar" on the keyboard. In AV trials, conditions of tone, visual cue or arrows were not presented. A red milliseconds down counter appeared in the center of the screen starting at 1000 and going down up to 0. Participants had to stop the counter, as fast as they could, by pressing any key on the keyboard. As in the other trials, responses were allowed up to 2000 ms since the down counter appearance (Figure 1). Participants were told to focus their attention on the fixation cross at every moment. Standard instructions were given for the three type of trials gradually. Starting with ANTI trials, a first practice block of 16 trials with visual feedback was run. After that, instructions about EV trials were given followed by a practice block of 32 trials with visual feedback, with a random presentation of 16 ANTI and 16 EV trials. In the end, instructions of AV trials were given, including an example of the milliseconds down counter. A last randomized practice block of 48 trials with visual feedback was presented, including 16 trials of each type. To ensure the correct understanding of instructions, an additional practice block of 40 randomized trials (24 ANTI, 8 EV and 8 AV i.e., half of one experimental block) without feedback was presented. Participants were told to consult the researcher for any doubt before starting the experimental blocks. The experimental section was composed of 6 blocks of 80 randomly presented trials (48

ANTI, 16 EV, and 16 AV per block). The 48 ANTI trials had the following factorial design: 2 (Warning: No tone/Tone) X 3 (Visual Cue: Invalid/No Cue/Valid) X 2 (Congruency: Congruent/Incongruent). The duration of the task was approximately 60 min.

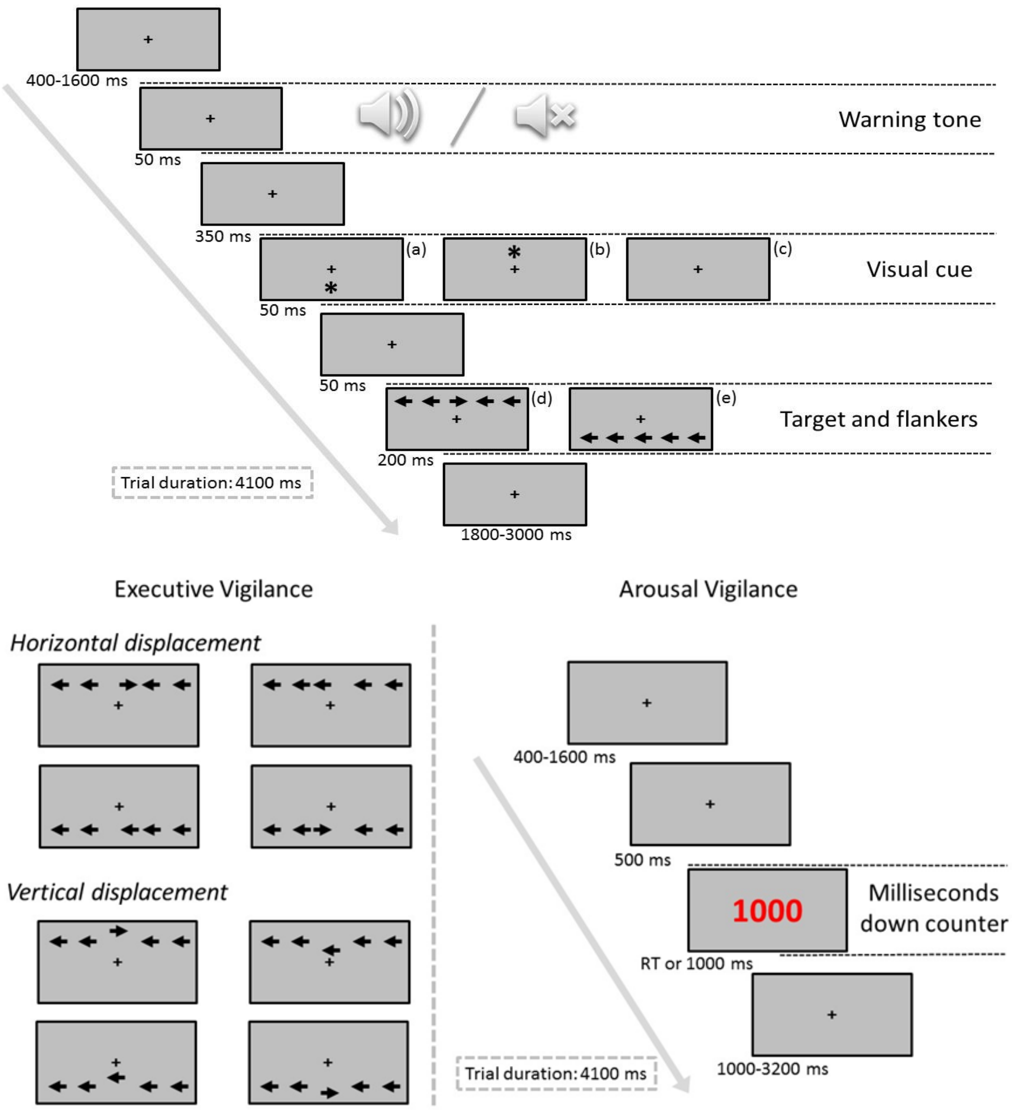

Figure 1. Stimuli sequence for ANTI trials, EV trials and AV trials in ANTI-Vea (Luna et al., *In preparation*)

2.3. Data analysis and results

For the ANTI trials, repeated measures ANOVAs were conducted for both RT and Errors %, including Warning signal (No tone/Tone), Visual cue (Invalid/No cue/Valid), and Congruency (Congruent/Incongruent) as within-participants factors. For RT analysis only correct responses and with RT between 200 ms and 1500 ms were included. Further, in order to analyze EV performance, Signal-Detection Theory (SDT) metrics were calculated for Hits (the proportion of infrequent signals as displaced targets) detected correctly, False Alarms (FA, the proportion of infrequent stimuli key response given to frequent stimuli as ANTI trials), d' (index of sensitivity) and Beta (β, response bias). Then, six repeated measures ANOVAs were conducted separately including task blocks as within-participants factors, one for each dependent variable. Finally, for the AV measures, repeated measures ANOVAs of mean RTs and Lapses (late responses) were conducted separately including task blocks as a within-participants factor. Lapses for ANTI-Vea task were defined as responses larger than 600 ms (Luna et al., *In preparation*). For RT results, significant main effects were found for the three within-participants variables: Warning signal [$F(1, 79) = 158{,}53$, $p < .001$], Visual cue [$F(2, 158) = 134{,}99$, $p < .001$] and Congruency [$F(1, 79) = 209{,}64$, $p < .001$]. As in previous study using ANTI task, all the interactions between conditions, except the three-way interaction between the within-participants factors, were significant in our experiment. For Accuracy (Errors %) results, significant main effects were found for the three within-participants variables: Warning signal [$F(1, 79) = 20{,}572$, $p < .001$], Visual cue [$F(2, 158) = 5{,}2039$, $p < .01$] and Congruency [$F(1, 79) = 5{,}4476$, $p < .05$]. As in previous study using ANTI task, no significant interactions between the within-participants factors were found in our experiment. For EV results, a significant main effect of blocks was observed for both Hits [$F(5, 390) = 14{,}755$, $p < .001$] and FAs [$F(5, 390) = 2{,}46$, $p < .05$]. Figure 2 shows that both Hits and FAs tend to decrease linearly with time on task. A significant main effect of blocks was only found for Response Bias (β) [$F(5, 390) = 5{,}2562$, $p < .001$], while Sensitivity (d') did not change significantly across blocks [$F(5, 390) = 4{,}9181$, $p < .001$]. Figure 3 shows that Sensitivity did not change with time on task whereas Response Bias tends to increase. For AV results, significant main effects of blocks were found in the two repeated measures ANOVAs: mean RT [$F(5, 390) = 2.3472$, $p < .05$] and Lapses percentage [$F(5, 390) = 5{,}1484$, $p < .001$]. Figure 4 shows that mean RT and Lapses percentage tend to increase linearly with time on task.

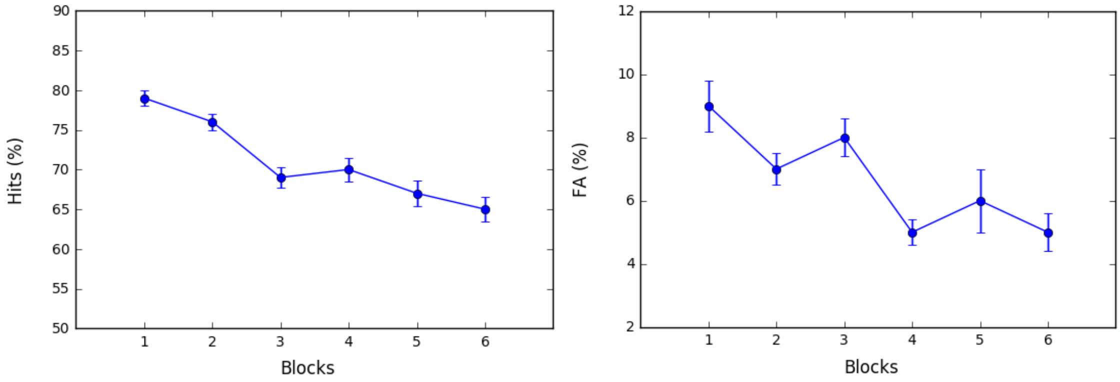

Figure 2. Executive Vigilance performance per blocks in ANTI-Vea task: Hits and FA

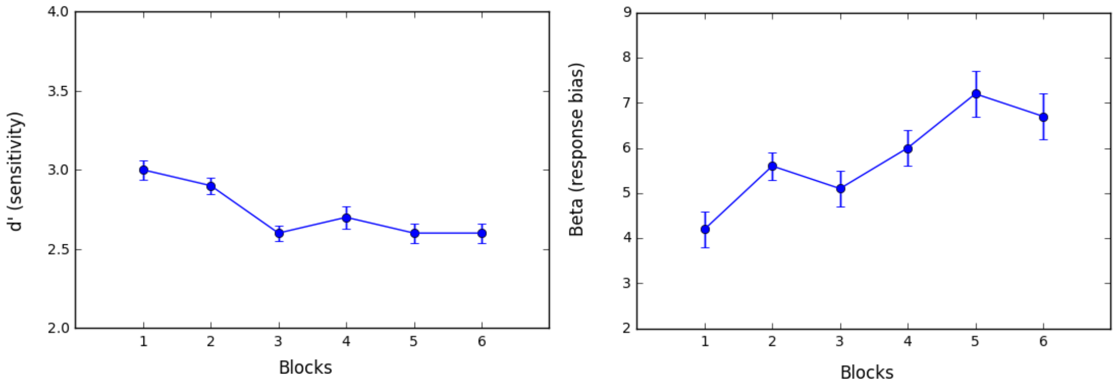

Figure 3. Executive Vigilance performance per blocks in ANTI-Vea task: d’ and Beta

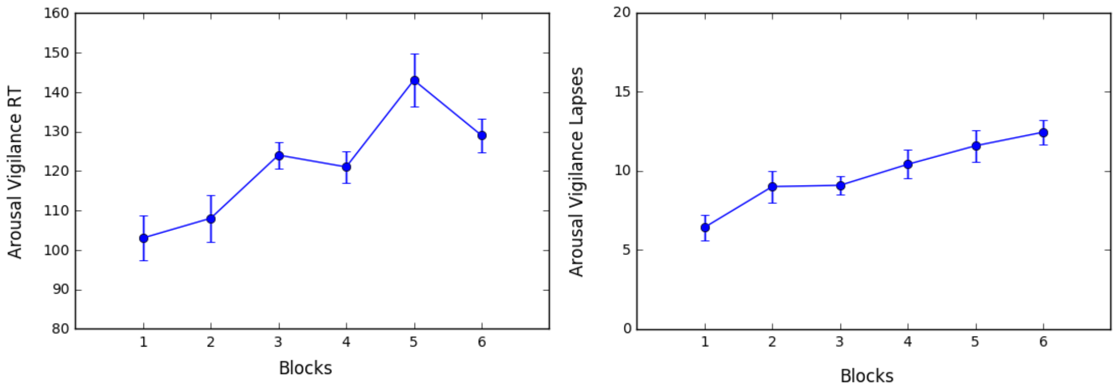

Figure 4. Arousal Vigilance performance per blocks in ANTI-Vea task: RT and Lapses

3. Discussion

The new attentional task (ANTI-Vea) proposed by Luna and collaborators would dissociate two different components of vigilance performance: one more ‘executive’ that is implicated in the detection of infrequent signals across time and another more involved in sustaining a tonic level of arousal through time but without a response control over stimuli. At the same time, the authors aimed to improve the measuring of the executive component of vigilance originally seen in Roca et al., (2011). Further, they expected to still find the typical functioning for phasic alertness, orienting and executive control (Callejas et al., 2004). The vertical version of ANTI-Vea task seems to resolve all the difficulties in measuring executive vigilance performance. Moreover, with this new task is now possible to approach the cognitive mechanisms that underlies the executive vigilance decrement across time, something that could not be observed in the ANTI-V studies (Roca et al., 2012). That is, the decrement of vigilance is seen, by many studies, as a loss in sensitivity. However, in ANTI-Vea vertical version, where subjects resolved three tasks simultaneously with a high cognitive load, it was not observed any change in sensitivity across time. Indeed, both hits and FA tend to decrease over time and this decrement was characterized as a change in response bias towards a more conservative criterion. This results could be interpreted as the confirmation of the empirical demonstration by Thomson et al., (2016) about the causes of the executive vigilance decrement. In addition, results may support the idea of the independence of vigilance components as proposed by Luna and collaborators. The time responses for executive vigilance did not showed any decrement, in contrast to the arousal vigilance measure. Sarter et al., (2001) proposed that vigilance or sustained attention may be thought up as separated from the “arousal” components of attention. They dissociated vigilance as a behavioral function for detection of unusual targets, which is supported by a top-down functioning of the cholinergic neural system whereas the “arousal” of attention did not involve a behaviorally component even if it could be necessary for the development of vigilance across time by the bottom-up innervations of the noradrenergic system. In Luna et al, (*In preparation*) as in the present study, both components of vigilance are independent from one another. The authors support this idea specifying what the type of responses are particular of each component, and we could observe the size and type of decrement for each of them. Finally, future neuroimaging and behavioral data could help to highlight the independence of these vigilance components.

Experiment 4

1. Introduction

Mindfulness could be described as "awareness that arises through paying attention, on purpose, in the present moment, non-judgementally" (Kabat-Zinn, 1990). Mindfulness means living in the moment and awakening to your current experience, rather than dwelling on the past or anticipating the future. The 39-item Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) has been developed as a reliable and valid comprehensive instrument for assessing different aspects of mindfulness in community and student samples. FFMQ questionnaire appears to be the most inclusive assessment of mindfulness at present. The Attention Network Test for Interactions and Vigilance - executive and arousal components (ANTI-Vea) measure simultaneously the functioning of the typical attentional networks (phasic alertness, orienting and executive control), together with two different components of vigilance (executive –detection of infrequent signals-, and arousal –immediate reaction without response control-) (see Experiment 1, for more details). The aim of this study was to investigate whether and how FFMQ mindfulness facets interacted with attentional performance using ANTI-Vea task. The inclusion of a new measure of vigilance performance (arousal component) could change again our mental set towards external stimuli (i.e., warning signal and milliseconds down counter). More generally, whether and how there is an interaction between the two mindfulness facets relative to attention (Observe and Acting with awareness) and the attentional performance.

2. Method

2.1. Participants

Forty participants took part in this study (range 17-35 years old with a mean of 20.09) from University of Granada for extra class credit. All participants had normal or corrected-to-normal vision and reported no clinical history of psychological or neurological problems.

2.2. Assessment

The Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) is a self-report measure assessing a general tendency to be mindful. This scale is composed of 39 items that are divided into five subscales or facets: observing, describing, acting with awareness, non-judging, and non-reactivity of experience. The *Observing* facet measures the tendency to notice or attend to internal and external experiences, such as sensations, emotions, cognitions, sounds, sights, and smells. Example items are "I remain present with sensations and feelings even when they are unpleasant or painful" and "I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing." *Describing* measures the tendency to describe and label these experiences with words. Items include "I'm good at finding the words to describe my feelings" and "My natural tendency is to put my experiences into words." The *Acting with awareness* facet refers to bringing full awareness and undivided attention to current activity or experiences. Example items are "I rush through activities without being really attentive to them" and "I find it difficult to stay focused on what's happening in the present." *Non-judging* refers to a non-evaluative stance toward inner experiences. Items include "I tend to evaluate whether my perceptions are right or wrong" and "I think some of my emotions are bad or inappropriate and I shouldn't feel them." *Non-reactivity* measures the tendency to allow thoughts and feelings to come and go, without getting caught up in them or carried away by them. Items include "Usually when I have distressing thoughts or images, I step back and am aware of the thought or image without getting taken over by it." The subscales include eight items, except the non-reactivity scale, which is composed of seven items. Each subscale is a Likert scale ranging from 1 (never or very rarely true) to 5 (very often or always true).

2.3. Materials and procedure

Procedure was identical to Experiment 3 except that trait/state mindfulness was assessed with the Spanish version of Five Facet Mindfulness Questionnaire (FFMQ, Cebolla et. al., 2012).

2.4. Data analysis and results

First, in our results we replicated all the main previous findings with the ANTI-Vea task (Luna et al., *In preparation*). As in the Experiment 2, these main effects of attentional indexes are not reported here, as they fall beyond the aim of the present study. Then, we computed the correlations between Observe and Acting with awareness and the ANTI-

Vea scores: both RT and Accuracy scores, Executive Vigilance and Arousal Vigilance indexes. Additionally, we conducted a series of multiple regression analyses, with the ANTI-Vea scores as dependent variables and the FFMQ facets scores as predictors. For Observe, the first analysis revealed significant correlations with Orienting RT, $r = .42$, $p < .05$ while for Acting with awareness we found a negative significant correlation only with Alerting RT, $r = -0.40$, $p < .05$. All other correlation analyses of ANTI scores were not significant (Table 1). On Executive Vigilance performance, we found a significant correlation only for Observe with Hits, $r = 0.33$, $p < .05$. All other correlation analyses of Executive Vigilance indexes were not significant (Table 2). Further, we did not found significant correlations for Arousal Vigilance indexes with any of the FFMQ facets considered. As reported in Table 3, we found a corresponding pattern of results for the regression analyses. The regression revealed that Observe significantly predicted the dependent variable Orienting RT, $\beta = .39$, $p < .05$. Moreover, Acting with awareness is a predictor of Alerting RT, $\beta = .30$, $p < .05$ and Observe is a predictor of the dependent variable Hits. All other regression analyses were not significant and not reported in Table 3.

Table 1. Correlation results: ANTI

	Alerting RT	**Orienting RT**	**Executive Control RT**
Observe	-0.14	0.40**	0.10
Acting with awareness	0.42**	-0.29	0.15
	Alerting Accuracy	**Orienting Accuracy**	**Executive Control Accuracy**
Observe	-0.10	0.10	-0.07
Acting with awareness	-0.19	0.09	0.22

**p < .05

Table 2. Correlation results: Executive Vigilance indexes

	Hits	**FA**	**d’**	**Beta**
Observe	.33**	.03	.27	.00
Acting with awareness	-.04	-.04	-.20	.25

**p < .05

Table 3. Regression analyses results

Dependent variable	*R*	*R*^{2}	*Adjusted R*^{2}	*F*	*Predictor*	*β*	*t*
Alerting RT	.42	.18	.15	8.34**	*Acting with awareness*	.41	2.75**
Orienting RT	.40	.16	.14	7.38**	*Observe*	.37	2.52**
Global Hits	.32	.10	.08	4.58**	*Observe*	.32	2.10**

**p < .05

3. Discussion

The aim of the study was to investigate the relation between FFMQ mindfulness questionnaire and a new task developed from ANT. ANTI-Vea include two different measure of vigilance performance: one more 'executive' that is implicated in the detection of infrequent signals across time and another more involved in sustaining a tonic level of arousal through time but without a response control over stimuli (Luna et al., *In preparation*). Observe facet interaction with attentional networks found in Di Francesco et al., (2016) was found again using ANTI-Vea task. ANTI-Vea task elicits a more open task set than ANTI-V task. More specifically, Observe facet measures the tendency to notice or attend to internal and external experiences, such as sensations, emotions, cognitions, sounds, sights, and smells. External stimuli (warning signal and milliseconds down counter) affected again participants' Observe facet. Further, Acting with awareness facet interaction with attentional performance found in Di Francesco et al., (2016) was found again using ANTI-Vea task. Acting with awareness facet refers to bringing full awareness and undivided attention to current activity or experiences. A different task could elicits a different mind-set in terms of involvement in the task. Future studies could better understand whether and how there is an interaction between FFMQ mindfulness facets and attentional performance using different task (i.e., memory task) together with attentional tasks. Finally, dispositional mindfulness could help to understand how our experience is centred in the present moment and the current activity. Although some people are naturally wired toward this type of keen self-awareness and present-focus, many studies suggest it can be cultivated by anyone. That is, individuals seem to differ in their natural tendency to be aware of their moment to moment experience in an open and non-judgmental way. Further research in larger populations is needed to confirm these findings, which may help shed further light on the mechanism of the beneficial effects of dispositional mindfulness.

General Discussion

The aim of this dissertation was to investigate whether and how mindfulness meditation could affect the attentional system. Most of the studies reviewed found significantly higher attentional performance in long term mindfulness meditators when compared with matched controls on different domains of attention as reported by meaningful results in this direction (Chiesa et al., 2011). On the other hand, the proportion of mindfulness-based interventions with statistically significant results may overstate what actually occurs in practice (Coronado-Montoya et al., 2016). Indeed, Heredia et al., (2017) found that a trained group with mindfulness intervention improved in subjective psychological wellness and emotional regulation, but not in attentional performance. In our Experiment 1, we also found effectiveness of MBSR training but no improvements in attentional performance. Mindfulness protocols used in the literature (i.e., MBSR, MBCT, short-term meditation or long-term meditation) could be unrelated to improvements in attentional processing. Lastly, it will be important for future research to utilize standardized cognitive measures so as to allow for comparisons across studies as well as comparing mindfulness groups with active control groups and other intervention programs. In Experiment 3, we replicated results from Luna et al., (*In preparation*). The authors developed a new task (ANTI-Vea) that could measure simultaneously the functioning of the typical attentional networks (phasic alertness, orienting and executive control), together with two different components of vigilance (executive –detection of infrequent signals-, and arousal –immediate reaction without response control-). Furthermore, with this new task, it is possible to dissociate the vigilance decrement observed for arousal vigilance (i.e., increased mean and/or variability in RT over time on task) from the vigilance decrement observed for the executive vigilance (i.e., reduced detection of infrequent targets with time on task). Finally, in Experiment 2 and 4, we found different results regarding the relationship between FFMQ mindfulness questionnaire and two attentional tasks: ANTI-V and ANTI-Vea. It could possible that different attentional trials may change overall task set. The ANTI-V task, because of its difficulty (i.e., executive vigilance trials together with attentional networks trials), may involve a more deeply attentional performance. On the contrary, the ANTI-Vea elicits a different mind-set in terms of involvement in the task in an open and non-judgmental way.

Limitations

Some limitations affected our studies. First, monitoring of MBSR daily activity could be improved since volunteers might have not constantly practice mindfulness exercises at home. Second, in our studies, we used FFMQ mindfulness questionnaire that is one of several assessments used in the literature. The development of a unique mindfulness questionnaire could solve actual problems relative to its dispositional measure. Third, it could also be useful to use different cognitive tasks (i.e., memory tasks) together with attentional tasks. Fourth, there is the need to explore different samples in both clinical and non-clinical populations. Future studies could achieve these aims and help us broaden our horizons to better understand the nature of attentional processing, its role in human functioning and its optimization. In addition, since neither current studies nor previous studies using FFMQ found correlations between mindfulness facets and Executive Control network it could be needed to develop a subscale that permits to measure cognitive control as a new facet of mindfulness meditation. Mindfulness training may be used to change habitual cognitive patterns of responding with intentional, flexible responses that are voluntarily chosen rather than automatic (Heeren et al., 2009).

Conclusions

In conclusion, interest in the psychological and neuroscientific investigation of mindfulness meditation has increased markedly over the past two decades. This resulting field of research is still in its early stages, and concomitant to its "green age" we need to explore deeply the mechanisms that underlie the effects of meditation. As suggested by Tang et al., (2015), if supported by rigorous research studies, the practice of mindfulness meditation might be promising for the treatment of clinical disorders and might facilitate the cultivation of a healthy mind and increased well-being. Moreover, attention is central to many higher order cognitive operations, influenced by dysfunction of normal aging, and impaired in many diseases and disorders. Consequently, improving attentional performance with training methods could be potentially beneficial in a wide range of domains.

References

Adólfsdóttir, S., Sørensen, L., & Lundervold, A. J. (2008). The attention network test: a characteristic pattern of deficits in children with ADHD. *Behavioral and Brain Functions*, *4*(1), 9.

Allport, G. W., & Odbert, H. S. (1936). Trait-names: A psycho-lexical study. *Psychological monographs*, *47*(1), i.

Anderson, N. D., Lau, M. A., Segal, Z. V., & Bishop, S. R. (2007). Mindfulness-based stress reduction and attentional control. *Clinical Psychology & Psychotherapy*, *14*(6), 449-463.

Aston-Jones, G., & Cohen, J. D. (2005). An integrative theory of locus coeruleus-norepinephrine function: adaptive gain and optimal performance. *Annu. Rev. Neurosci.*, *28*, 403-450.

Baer, R. A. (2003). Mindfulness training as a clinical intervention: A conceptual and empirical review. *Clinical psychology: Science and practice*, *10*(2), 125-143.

Baer, R. A., Smith, G. T., & Allen, K. B. (2004). Assessment of mindfulness by self-report: The Kentucky Inventory of Mindfulness Skills. *Assessment*, *11*(3), 191-206.

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment*, *13*(1), 27-45.

Baer, R. A., Walsh, E., & Lykins, E. L. (2009). Assessment of mindfulness. In *Clinical handbook of mindfulness* (pp. 153-168). Springer New York.

Bishop, S. R. (2002). What do we really know about mindfulness-based stress reduction?. *Psychosomatic medicine*, *64*(1), 71-83.

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., ... & Devins, G. (2004). Mindfulness: A proposed operational definition. *Clinical psychology: Science and practice*, *11*(3), 230-241.

Block, N. (2005). Two neural correlates of consciousness. *Trends in cognitive sciences*, *9*(2), 46-52.

Bodhi, B. (2000). *The connected discourses of the Buddha* (p. 2080). Wisdom Publications.

Bohlmeijer, E., ten Klooster, P. M., Fledderus, M., Veehof, M., & Baer, R. (2011). Psychometric properties of the five facet mindfulness questionnaire in depressed adults and development of a short form. *Assessment*, *18*(3), 308-320.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological review*, *108*(3), 624.

Broadbent, D. E. (1958). Perception and communication. Oxford, UK: Pergamon.

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: mindfulness and its role in psychological well-being. *Journal of personality and social psychology*, *84*(4), 822.

Brown, K. W., Ryan, R. M., Loverich, T. M., Biegel, G. M., & West, A. M. (2011). Out of the armchair and into the streets: Measuring mindfulness advances knowledge and improves interventions: Reply to Grossman (2011).

Brown, K. W., Ryan, R. M., & Creswell, J. D. (2007). Mindfulness: Theoretical foundations and evidence for its salutary effects. *Psychological inquiry*, *18*(4), 211-237.

Buchheld, N., Grossman, P., & Walach, H. (2001). Measuring mindfulness in insight meditation (Vipassana) and meditationbased psychotherapy: The development of the Freiburg Mindfulness Inventory (FMI).

Bukowski, M., Asanowicz, D., Marzecová, A., & Lupiáñez, J. (2015). Limits of control: The effects of uncontrollability experiences on the efficiency of attentional control. *Acta psychologica*, *154*, 43-53.

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in cognitive sciences*, *4*(6), 215-222.

Callejas, A., Lupiáñez, J., & Tudela, P. (2004). The three attentional networks: On their independence and interactions. *Brain and cognition*, *54*(3), 225-227.

Callejas, A., Lupiàñez, J., Funes, M. J., & Tudela, P. (2005). Modulations among the alerting, orienting and executive control networks. *Experimental brain research*, *167*(1), 27-37.

Canas, J., Quesada, J., Antolí, A., & Fajardo, I. (2003). Cognitive flexibility and adaptability to environmental changes in dynamic complex problem-solving tasks. *Ergonomics*, *46*(5), 482-501.

Cave, K. R., & Wolfe, J. M. (1990). Modeling the role of parallel processing in visual search. *Cognitive psychology*, *22*(2), 225-271.

Cardaciotto, L., Herbert, J. D., Forman, E. M., Moitra, E., & Farrow, V. (2008). The assessment of present-moment awareness and acceptance: The Philadelphia Mindfulness Scale. *Assessment*, *15*(2), 204-223.

Cebolla, A., García-Palacios, A., Soler, J., Guillen, V., Baños, R., & Botella, C. (2012). Psychometric properties of the Spanish validation of the Five Facets of Mindfulness Questionnaire (FFMQ). *The European Journal of Psychiatry*, *26*(2), 118-126.

Chadwick, P., Hember, M., Symes, J., Peters, E., Kuipers, E., & Dagnan, D. (2008). Responding mindfully to unpleasant thoughts and images: reliability and validity of the Southampton mindfulness questionnaire (SMQ). *British Journal of Clinical Psychology*, *47*(4), 451-455.

Chambers, R., Gullone, E., & Allen, N. B. (2009). Mindful emotion regulation: An integrative review. *Clinical psychology review*, *29*(6), 560-572.

Chambers, R., Lo, B. C. Y., & Allen, N. B. (2008). The impact of intensive mindfulness training on attentional control, cognitive style, and affect. *Cognitive therapy and research*, *32*(3), 303-322.

Chan, R. C., Shum, D., Toulopoulou, T., & Chen, E. Y. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of clinical neuropsychology*, *23*(2), 201-216.

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clinical psychology review*, *31*(3), 449-464.

Chiesa, A., & Malinowski, P. (2011). Mindfulness-based approaches: are they all the same?. *Journal of clinical psychology*, *67*(4), 404-424.

Chiesa, A., & Serretti, A. (2011). Mindfulness based cognitive therapy for psychiatric disorders: a systematic review and meta-analysis. *Psychiatry research*, *187*(3), 441-453.

Cohen, N., Henik, A., & Mor, N. (2010). Can emotion modulate attention? Evidence for reciprocal links in the attentional network test. *Experimental psychology*.

Coull, J. T., Frith, C. D., Büchel, C., & Nobre, A. C. (2000). Orienting attention in time: behavioural and neuroanatomical distinction between exogenous and endogenous shifts. *Neuropsychologia*, *38*(6), 808-819.

Corbetta, M., Akbudak, E., Conturo, T. E., Snyder, A. Z., Ollinger, J. M., Drury, H. A., ... & Shulman, G. L. (1998). A common network of functional areas for attention and eye movements. *Neuron*, *21*(4), 761-773.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature reviews. Neuroscience*, *3*(3), 201.

Coronado-Montoya, S., Levis, A. W., Kwakkenbos, L., Steele, R. J., Turner, E. H., & Thombs, B. D. (2016). Reporting of positive results in randomized controlled trials of mindfulness-based mental health interventions. *PloS one*, *11*(4), e0153220.

Cowen, E. L., Wiener, M., & Hess, J. (1953). Generalization of problem-solving rigidity. *Journal of Consulting Psychology*, *17*(2), 100.

Davis, D. M., & Hayes, J. A. (2011). What are the benefits of mindfulness? A practice review of psychotherapy-related research. *Psychotherapy*, *48*(2), 198.

Dehaene, S., & Changeux, J. P. (2011). Experimental and theoretical approaches to conscious processing. *Neuron*, *70*(2), 200-227.

Dehaene, S., Posner, M. I., & Tucker, D. M. (1994). Localization of a neural system for error detection and compensation. *Psychological Science*, *5*(5), 303-305.

Deikman, A. J. (1966). Implications of experimentally induced contemplative meditation. *The Journal of nervous and mental disease*, *142*(2), 101-116.

Deng, Y. Q., Liu, X. H., Rodriguez, M. A., & Xia, C. Y. (2011). The five facet mindfulness questionnaire: Psychometric properties of the Chinese version. *Mindfulness*, *2*(2), 123-128.

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological review*, *70*(1), 80.

De Weerd, P. (2003a). Attention, neural basis of. In L. Nadel (Ed.), Encyclopedia of cognitive science (Vol. 1, pp. 238–246). London: Nature Publishing Group.

Di Francesco, S. A., Simione, L., López-Ramón, M. F., Belardinelli, M. O., Lupiáñez, J., & Raffone, A. (2017). Dispositional mindfulness facets predict the efficiency of attentional networks. *Mindfulness*, *8*(1), 101-109.

Driver J, Eimer M, Macaluso E, van Velzen J. (2004). Neurobiology of human spatial attention: modulation, generation, and integration. See Kanwisher & Duncan 2004, pp. 267–300

Duncan, J. (1980). The locus of interference in the perception of simultaneous stimuli. *Psychological review*, *87*(3), 272.

Duncan, J., & Humphreys, G. W. (1989). Visual search and stimulus similarity. *Psychological review*, *96*(3), 433.

Dundas, I., Vøllestad, J., Binder, P. E., & Sivertsen, B. (2013). The five factor mindfulness questionnaire in Norway. *Scandinavian Journal of Psychology*, *54*(3), 250-260.

Eisenberger, N. I., Lieberman, M. D., & Williams, K. D. (2003). Does rejection hurt? An fMRI study of social exclusion. *Science*, *302*(5643), 290-292.

Elliott, R. (2003). Executive functions and their disorders: Imaging in clinical neuroscience. *British medical bulletin*, *65*(1), 49-59.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Attention, Perception, & Psychophysics*, *16*(1), 143-149.

Everitt, B. J., & Robbins, T. W. (1997). Central cholinergic systems and cognition. *Annual review of psychology*, *48*(1), 649-684.

Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *Neuroimage*, *26*(2), 471-479.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of cognitive neuroscience*, *14*(3), 340-347.

Farb, N. A., Segal, Z. V., Anderson, A.K. (2013). Mindfulness meditation training alters cortical representations of interoceptive attention. *Social, Cognitive and Affective Neuroscience, 8(1),* 15-26.

Farb, N. A., Segal, Z. V., Mayberg, H., Bean, J., McKeon, D., Fatima, Z., & Anderson, A. K. (2007). Attending to the present: mindfulness meditation reveals distinct neural modes of self-reference. *Social, Cognitive and Affective Neuroscience*, *2*(4), 313-322.

Feldman, G., Hayes, A., Kumar, S., Greeson, J., & Laurenceau, J. P. (2007). Mindfulness and emotion regulation: The development and initial validation of the Cognitive and Affective Mindfulness Scale-Revised (CAMS-R). *Journal of Psychopathology and Behavioral Assessment*, *29*(3), 177-190.

Forgays, D. G., Forgays, D. K., & Spielberger, C. D. (1997). Factor structure of the state-trait anger expression inventory. *Journal of personality assessment*, *69*(3), 497-507.

Frankmann, J. P., & Adams, J. A. (1962). Theories of vigilance. *Psychological Bulletin*, *59*(4), 257.

Giovannini, C., Giromini, L., Bonalume, L., Tagini, A., Lang, M., & Amadei, G. (2014). The Italian five facet mindfulness questionnaire: a contribution to its validity and reliability. *Journal of Psychopathology and Behavioral Assessment*, *36*(3), 415-423.

Greenberg, J., Reiner, K., & Meiran, N. (2012). “Mind the trap”: mindfulness practice reduces cognitive rigidity. *PloS one*, *7*(5), e36206.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *Journal of personality and social psychology*, *85*(2), 348.

Grossman, P. (2008). On measuring mindfulness in psychosomatic and psychological research. *Journal of psychosomatic research*, *64*(4), 405-408.

Grossman, P. (2011). Defining mindfulness by how poorly I think I pay attention during everyday awareness and other intractable problems for psychology's (re) invention of mindfulness: comment on Brown et al.(2011).

Grossman, P., Niemann, L., Schmidt, S., & Walach, H. (2004). Mindfulness-based stress reduction and health benefits: A meta-analysis. *Journal of psychosomatic research*, *57*(1), 35-43.

Grossman, P., & Van Dam, N. T. (2011). Mindfulness, by any other name…: trials and tribulations of sati in western psychology and science. *Contemporary Buddhism*, *12*(01), 219-239.

Hampton, A. N., & O'Doherty, J. P. (2007). Decoding the neural substrates of reward-related decision making with functional MRI. *Proceedings of the national Academy of sciences, 104*(4), 1377-1382.

Hargus, E., Crane, C., Barnhofer, T., & Williams, J. M. G. (2010). Effects of mindfulness on meta-awareness and specificity of describing prodromal symptoms in suicidal depression. *Emotion, 10*(1), 34.

Hamaker, E. L., Nesselroade, J. R., & Molenaar, P. C. (2007). The integrated trait–state model. *Journal of Research in Personality*, *41*(2), 295-315.

Hayes, S. C., Strosahl, K. D., & Wilson, K. G. (1999). *Acceptance and commitment therapy: An experiential approach to behavior change*. Guilford Press.

Heeren, A., Douilliez, C., Peschard, V., Debrauwere, L., & Philippot, P. (2011). Cross-cultural validity of the Five Facets Mindfulness Questionnaire: Adaptation and validation in a French-speaking sample. *Revue européenne de psychologie appliquée/European Review of Applied Psychology*, *61*(3), 147-151.

Heeren, A., & Philippot, P. (2011). Changes in ruminative thinking mediate the clinical benefits of mindfulness: Preliminary findings. *Mindfulness, 2*(1), 8-13.

Heeren, A., Van Broeck, N., & Philippot, P. (2009). The effects of mindfulness on executive processes and autobiographical memory specificity. *Behaviour research and therapy, 47*(5), 403-409.

Helton, W. S., Hollander, T. D., Warm, J. S., Tripp, L. D., Parsons, K., Matthews, G., ... & Hancock, P. A. (2007). The abbreviated vigilance task and cerebral hemodynamics. *Journal of Clinical and Experimental Neuropsychology*, *29*(5), 545-552.

Heredia, L., Gasol, L., Ventura, D., Vicens, P., & Torrente, M. (2017). Mindfulness-based stress reduction training program increases psychological well-being, and emotional regulation, but not attentional performance. A pilot study. *Mindfulness & Compassion*.

Hill, C. L., & Updegraff, J. A. (2012). Mindfulness and its relationship to emotional regulation. *Emotion, 12*(1), 81.

Hodgins, H. S., & Adair, K. C. (2010). Attentional processes and meditation. *Consciousness and cognition*, *19*(4), 872-878.

Hölzel, B. K., Carmody, J., Vangel, M., Congleton, C., Yerramsetti, S. M., Gard, T., & Lazar, S. W. (2011). Mindfulness practice leads to increases in regional brain gray matter density. *Psychiatry Research: Neuroimaging*, *191*(1), 36-43.

Hubel, D. H., & Wiesel, T. N. (1979). *Brain mechanisms of vision*. WH Freeman.

Hülsheger, U. R., Alberts, H. J., Feinholdt, A., & Lang, J. W. (2013). Benefits of mindfulness at work: The role of mindfulness in emotion regulation, emotional exhaustion, and job satisfaction. *Journal of Applied Psychology*, *98*(2), 310.

Ishigami, Y., & Klein, R. M. (2011). Repeated measurement of the components of attention of older adults using the two versions of the attention network test: stability, isolability, robustness, and reliability. *Frontiers in aging neuroscience, 3*.

Jensen, C. G., Vangkilde, S., Frokjaer, V., & Hasselbalch, S. G. (2012). Mindfulness training affects attention—or is it attentional effort?. *Journal of Experimental Psychology: General*, *141*(1), 106.

Jha, A. P., Krompinger, J., & Baime, M. J. (2007). Mindfulness training modifies subsystems of attention. *Cognitive, Affective, & Behavioral Neuroscience, 7*(2), 109-119.

Jha, A. P., Stanley, E. A., Kiyonaga, A., Wong, L., & Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion*, *10*(1), 54.

Kabat-Zinn, J. (1990). Full catastrophe living: The program of the stress reduction clinic at the University of Massachusetts Medical Center.

Kabat-Zinn J. (1994). Wherever you go, there you are: Mindfulness meditation in everyday life. Hyperion Books.

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: past, present, and future. *Clinical psychology: Science and practice*, *10*(2), 144-156.

Kahneman, D. (1973). Attention and effort. Englewood Cliffs, NJ: Prentice-Hall.

Kampe, K. K., Frith, C. D., & Frith, U. (2003). "Hey John": signals conveying communicative intention toward the self activate brain regions associated with "mentalizing," regardless of modality. *Journal of Neuroscience*, *23*(12), 5258-5263.

Kantor, L., Endler, N. S., Heslegrave, R. J., & Kocovski, N. L. (2001). Validating self-report measures of state and trait anxiety against a physiological measure. *Current Psychology*, *20*(3), 207-215.

Kellermann, T., Reske, M., Jansen, A., Satrapi, P., Shah, N. J., Schneider, F., & Habel, U. (2011). Latencies in BOLD response during visual attention processes. *Brain research*, *1386*, 127-138.

Langer, E. J. (2004). Langer mindfulness scale user guide and technical manual. *Covenington, IL: IDS.*

Lau, M. A., Bishop, S. R., Segal, Z. V., Buis, T., Anderson, N. D., Carlson, L., ... & Devins, G. (2006). The Toronto mindfulness scale: Development and validation. *Journal of clinical psychology*, *62*(12), 1445-1467.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human perception and performance*, *21*(3), 451.

Lavie, N., Hirst, A., De Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, *133*(3), 339.

Lazar, S. W., Kerr, C. E., Wasserman, R. H., Gray, J. R., Greve, D. N., Treadway, M. T., ... & Rauch, S. L. (2005). Meditation experience is associated with increased cortical thickness. *Neuroreport*, *16*(17), 1893.

LeDoux, J. E. (1995). Emotion: Clues from the brain. *Annual review of psychology*, *46*(1), 209-235.

Lilja, J. L., Frodi-Lundgren, A., Hanse, J. J., Josefsson, T., Lundh, L. G., Sköld, C., ... & Broberg, A. G. (2011). Five facets mindfulness questionnaire—reliability and factor structure: a Swedish version. *Cognitive Behaviour Therapy*, *40*(4), 291-303.

Linehan, M. M. (1987). Dialectical behavior therapy for borderline personality disorder: Theory and method. *Bulletin of the Menninger Clinic*, *51*(3), 261.

Luchins, A. S. (1942). Mechanization in problem solving: The effect of Einstellung. *Psychological monographs*, *54*(6), i.

Malinowski, P. (2008). Mindfulness as psychological dimension: concepts and applications. *The Irish Journal of Psychology*, *29*(1-2), 155-166.

Mackworth, N. H. (1948). The breakdown of vigilance during prolonged visual search. *Quarterly Journal of Experimental Psychology*, *1*(1), 6-21.

Mackie, R. R. (1984). Research relevance and the information glut. *Human factors review*, 1-11.

McDowd, J. M. (2007). An overview of attention: behavior and brain. *Journal of Neurologic Physical Therapy*, *31*(3), 98-103.

Medvedev, O. N., Krägeloh, C. U., Narayanan, A., & Siegert, R. J. (2017). Measuring Mindfulness: Applying Generalizability Theory to Distinguish between State and Trait. *Mindfulness*, 1-11.

Meiran, N., Hsieh, S., & Dimov, E. (2010). Resolving task rule incongruence during task switching by competitor rule suppression. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(4), 992.

Monsell, S. (2003). Task switching. *Trends in cognitive sciences*, *7*(3), 134-140.

Moore, A., & Malinowski, P. (2009). Meditation, mindfulness and cognitive flexibility. *Consciousness and cognition*, *18*(1), 176-186.

Morales, J., Padilla, F., Gómez-Ariza, C. J., & Bajo, M. T. (2015). Simultaneous interpretation selectively influences working memory and attentional networks. *Acta psychologica*, *155*, 82-91.

Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly journal of experimental psychology*, *11*(1), 56-60.

Nagai, Y., Critchley, H. D., Featherstone, E., Fenwick, P. B. C., Trimble, M. R., & Dolan, R. J. (2004). Brain activity relating to the contingent negative variation: an fMRI investigation. *Neuroimage*, *21*(4), 1232-1241.

Navalpakkam, V., & Itti, L. (2007). Search goal tunes visual features optimally. *Neuron*, *53*(4), 605-617.

Navon, D. (1984). Resources—A theoretical soup stone?. *Psychological review*, *91*(2), 216.

Neisser, U. (1967). Cognitive psychology. New York: Appleton- Century-Crofts.

Neuhaus, A. H., Urbanek, C., Opgen-Rhein, C., Hahn, E., Ta, T. M. T., Koehler, S., ... & Dettling, M. (2010). Event-related potentials associated with Attention Network Test. *International Journal of Psychophysiology*, *76*(2), 72-79.

Norman, D. A. (1968). Toward a theory of memory and attention. *Psychological review*, *75*(6), 522.

Norman, D. A., & Shallice, T. (1986). Attention to action. In *Consciousness and self-regulation* (pp. 1-18). Springer US.

Parasuraman, R. (1986). Vigilance, monitoring, and search.

Parasuraman, R., & Davies, D. R. (1977). A taxonomic analysis of vigilance performance. In *Vigilance* (pp. 559-574). Springer US.

Pashler, H., & Wagenmakers, E. J. (2012). Editors' introduction to the special section on replicability in psychological science: A crisis of confidence?. *Perspectives on Psychological Science*, *7*(6), 528-530.

Pessoa, L. (2005). To what extent are emotional visual stimuli processed without attention and awareness?. *Current opinion in neurobiology*, *15*(2), 188-196.

Pessoa, L. (2009). How do emotion and motivation direct executive control?. *Trends in cognitive sciences*, *13*(4), 160-166.

Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual review of neuroscience*, *35*, 73-89.

Pirson, M., Langer, E. J., Bodner, T., & Zilcha-Mano, S. (2012). The development and validation of the Langer mindfulness scale-enabling a socio-cognitive perspective of mindfulness in organizational contexts.

Pouget, A., & Bavelier, D. (2007). Paying attention to neurons with discriminating taste. *Neuron*, *53*(4), 473-475.

Posner, M. I. (1980). Orienting of attention. *Quarterly journal of experimental psychology*, *32*(1), 3-25.

Posner, M. I. (2008). Measuring alertness. *Annals of the New York Academy of Sciences, 1129*(1), 193-199.

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual review of neuroscience*, *13*(1), 25-42.

Posner, M. I., & Raichle, M. E. (1994). *Images of mind*. Scientific American Library/Scientific American Books.

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annu. Rev. Psychol.*, *58*, 1-23.

Posner, M. I., Sheese, B. E., Odludaş, Y., & Tang, Y. (2006). Analyzing and shaping human attentional networks. *Neural networks*, *19*(9), 1422-1429.

Rainville, P., Duncan, G. H., Price, D. D., Carrier, B., & Bushnell, M. C. (1997). Pain affect encoded in human anterior cingulate but not somatosensory cortex. *Science*, *277*(5328), 968-971.

Ramel, W., Goldin, P. R., Carmona, P. E., & McQuaid, J. R. (2004). The effects of mindfulness meditation on cognitive processes and affect in patients with past depression. *Cognitive therapy and research*, *28*(4), 433-455.

Rao, R. P. N. (2003). Attention, models of. In L. Nadel (Ed.), Encyclopedia of cognitive science (Vol. 1, pp. 231–237). London: Nature Publishing Group.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink?. *Journal of experimental psychology: Human perception and performance*, *18*(3), 849.

Rizzolatti, G., Riggio, L., Dascola, I., & Umiltá, C. (1987). Reorienting attention across the horizontal and vertical meridians: evidence in favor of a premotor theory of attention. *Neuropsychologia*, *25*(1), 31-40.

Roca, J., Castro, C., López-Ramón, M. F., & Lupiánez, J. (2011). Measuring vigilance while assessing the functioning of the three attentional networks: The ANTI-Vigilance task. *Journal of neuroscience methods*, *198*(2), 312-324.

Roca, J., Fuentes, L. J., Marotta, A., López-Ramón, M. F., Castro, C., Lupiáñez, J., & Martella, D. (2012). The effects of sleep deprivation on the attentional functions and vigilance. *Acta psychologica*, *140*(2), 164-176.

Roca, J., Lupiáñez, J., López-Ramón, M. F., & Castro, C. (2013). Are drivers' attentional lapses associated with the functioning of the neurocognitive attentional networks and with cognitive failure in everyday life?. *Transportation research part F: traffic psychology and behaviour*, *17*, 98-113.

Roemer, L., & Orsillo, S. M. (2002). Expanding our conceptualization of and treatment for generalized anxiety disorder: Integrating mindfulness/acceptance-based approaches with existing cognitive-behavioral models. *Clinical Psychology: Science and Practice*, *9*(1), 54-68.

Roemer, L., & Orsillo, S. M. (2003). Mindfulness: A promising intervention strategy in need of further study. *Clinical psychology: Science and practice*, *10*(2), 172-178.

Rosenberg, M., Noonan, S., DeGutis, J., & Esterman, M. (2013). Sustaining visual attention in the face of distraction: a novel gradual-onset continuous performance task. *Attention, Perception, & Psychophysics*, *75*(3), 426-439.

Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia*, *42*(8), 1029-1040.

Ruocco, A. C., & Direkoglu, E. (2013). Delineating the contributions of sustained attention and working memory to individual differences in mindfulness. *Personality and Individual Differences*, *54*(2), 226-230.

Safran, J. D., & Segal, Z. V. (1990). Interpersonal Process in Cognitive Therapy. New York: Basic Boks.

Sarter, M., Givens, B., & Bruno, J. P. (2001). The cognitive neuroscience of sustained attention: where top-down meets bottom-up. *Brain research reviews*, *35*(2), 146-160.

Schmertz, S. K., Anderson, P. L., & Robins, D. L. (2009). The relation between self-report mindfulness and performance on tasks of sustained attention. *Journal of Psychopathology and Behavioral Assessment*, *31*(1), 60-66.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological review*, *84*(1), 1.

Schultz, P. W., & Searleman, A. (1998). Personal need for structure, the Einstellung task, and the effects of stress. *Personality and Individual Differences*, *24*(3), 305-310.

Sedlmeier, P., Eberth, J., Schwarz, M., Zimmermann, D., Haarig, F., Jaeger, S., & Kunze, S. (2012). The psychological effects of meditation: A meta-analysis. *Psychological bulletin*, *138*(6), 1139.

Segal, Z. V., Williams, J. M. G., & Teasdale, J. D. (2002). Mindfulness-based cognitive therapy for depression: A new approach to relapse prevention. *New York: Guilford*.

Semple, R. J. (2010). Does mindfulness meditation enhance attention? A randomized controlled trial. *Mindfulness*, *1*(2), 121-130.

Shapiro, K. L., Raymond, J. E., & Arnell, K. M. (1997). The attentional blink. *Trends in cognitive sciences*, *1*(8), 291-296.

Shapiro, S. L., Carlson, L. E., Astin, J. A., & Freedman, B. (2006). Mechanisms of mindfulness. *Journal of clinical psychology, 62*(3), 373-386.

Slagter, H. A., Lutz, A., Greischar, L. L., Francis, A. D., Nieuwenhuis, S., Davis, J. M., & Davidson, R. J. (2007). Mental training affects distribution of limited brain resources. *PLoS biology*, *5*(6), e138.

Solloway, S. G., & Fisher, W. P. (2007). Mindfulness practice: A Rasch variable construct innovation. *Journal of Applied Measurement*, *8*(4), 359.

Spielberger, C. D., & Sydeman, S. J. (1994). State-Trait Anxiety Inventory and State-Trait Anger Expression Inventory.

Sternberg, R. J., & Sternberg, K. (2012). *Cognitive psychology*. Nelson Education.

Stewart, C., Burke, S., & Marrocco, R. (2001). Cholinergic modulation of covert attention in the rat. *Psychopharmacology, 155*(2).

Sturm, W., & Willmes, K. (2001). On the functional neuroanatomy of intrinsic and phasic alertness. *Neuroimage*, *14*(1), S76-S84.

Sugiura, Y., Sato, A., Ito, Y., & Murakami, H. (2012). Development and validation of the Japanese version of the Five Facet Mindfulness Questionnaire. *Mindfulness, 3*(2), 85-94.

Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews. Neuroscience*, *16*(4), 213.

Tang, Y. Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., ... & Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences*, *104*(43), 17152-17156.

Teasdale, J. D. (1999). Emotional processing, three modes of mind and the prevention of relapse in depression. *Behaviour research and therapy*, *37*, S53-S77.

Teasdale, J. D., Segal, Z., & Williams, J. M. G. (1995). How does cognitive therapy prevent depressive relapse and why should attentional control (mindfulness) training help?. *Behaviour Research and therapy*, *33*(1), 25-39.

Teichner, W. H., & Krebs, M. J. (1974). Laws of visual choice reaction time. *Psychological review, 81*(1), 75.

Thera, N. (1962). *Satipatthana: The heart of Buddhist meditation: A handbook of mental training based on the Buddha's way of mindfulness*. Rider.

Thomson, D. R., Besner, D., & Smilek, D. (2016). A critical examination of the evidence for sensitivity loss in modern vigilance tasks. *Psychological review*, *123*(1), 70.

Thompson, K. G., Biscoe, K. L., & Sato, T. R. (2005). Neuronal basis of covert spatial attention in the frontal eye field. *Journal of Neuroscience, 25*(41), 9479-9487.

Treisman, A. (1964). Monitoring and storage of irrelevant messages in selective attention. *Journal of Verbal Learning and Verbal Behavior, 3*(6), 449-459.

Treisman, A. M. (1964b). Selective attention in man. British Medical Bulletin, 20, 12–16.

Treisman, A. M. (1993). The perception of features and objects. En A. Baddeley y L. Weiskrantz (Eds.), Attention: Selection, awareness, and control (págs. 5-34).

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive psychology*, *12*(1), 97-136.

Treisman, A., & Sato, S. (1990). Conjunction search revisited. *Journal of experimental psychology: human perception and performance*, *16*(3), 459.

Treisman, A., & Schmidt, H. (1982). Illusory conjunctions in the perception of objects. *Cognitive psychology*, *14*(1), 107-141.

van den Hurk, P. A., Giommi, F., Gielen, S. C., Speckens, A. E., & Barendregt, H. P. (2010). Greater efficiency in attentional processing related to mindfulness meditation. *The Quarterly Journal of Experimental Psychology*, *63*(6), 1168-1180.

van Leeuwen, S., Müller, N. G., & Melloni, L. (2009). Age effects on attentional blink performance in meditation. *Consciousness and cognition*, *18*(3), 593-599.

Vestergaard-Poulsen, P., van Beek, M., Skewes, J., Bjarkam, C. R., Stubberup, M., Bertelsen, J., & Roepstorff, A. (2009). Long-term meditation is associated with increased gray matter density in the brain stem. *Neuroreport*, *20*(2), 170-174.

Voytko, M. L., Olton, D. S., Richardson, R. T., Gorman, L. K., Tobin, J. R., & Price, D. L. (1994). Basal forebrain lesions in monkeys disrupt attention but not learning and memory [published erratum appears in J Neurosci 1995 Mar; 15 (3): following table of contents]. *Journal of Neuroscience*, *14*(1), 167-186.

Walter, W. G., Cooper, R., Aldridge, V. J., McCallum, W. C., & Winter, A. L. (1964). Contingent negative variation: an electric sign of sensori-motor association and expectancy in the human brain. *Nature*, *203*(4943), 380-384.

Weidner, R., & Müller, H. J. (2009). Dimensional weighting of primary and secondary target-defining dimensions in visual search for singleton conjunction targets. *Psychological research*, *73*(2), 198-211.

Wenk-Sormaz, H. (2005). Meditation can reduce habitual responding. *Alternative therapies in health and medicine*, *11*(2), 42.

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological bulletin*, *120*(1), 3.

Williams, J. M., Teasdale, J. D., Segal, Z. V., & Soulsby, J. (2000). Mindfulness-based cognitive therapy reduces overgeneral autobiographical memory in formerly depressed patients. *Journal of abnormal psychology, 109*(1), 150-155.

Wolfe, J. M. (2007). Guided search 4.0. *Integrated models of cognitive systems*, 99-119.

Wood, N., & Cowan, N. (1995). The cocktail party phenomenon revisited: how frequent are attention shifts to one's name in an irrelevant auditory channel?. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(1), 255.

Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness and cognition*, *19*(2), 597-605.

Zylowska, L., Ackerman, D. L., Yang, M. H., Futrell, J. L., Horton, N. L., Hale, T. S., ... & Smalley, S. L. (2008). Mindfulness meditation training in adults and adolescents with ADHD: a feasibility study. *Journal of Attention Disorders*, *11*(6), 737-746.

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Ora viene la parte più difficile di questi ringraziamenti e voglio fare una premessa: tutti coloro che compariranno in questa sezione sappiano che mi è impossibile trovare parole per esprimere quello che provo per loro. Non scriverò nulla di personalizzato perché, come insegnano i teorici della Gestalt, il tutto non è la semplice somma delle sue parti. E voi siete il mio tutto.

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