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Universidade Federal do Rio de Janeiro -UFRJ

Alterações Eletroencefalográficas Durante a Prática de Meditação Mindfulness

Guaraci Ken Tanaka

Supervisão:

Profa. Dra. Bruna Velasques

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GUARACI KEN TANAKA

Dissertação de Mestrado submetida ao corpo docente do Programa de Pós-Graduação em Saúde Mental do Instituto de Psiquiatria da Universidade Federal do Rio de Janeiro – UFRJ, como parte dos requisitos necessários à obtenção do grau de Mestre em Saúde Mental.

Orientador (a): Dra. Bruna Velasques

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ALTERAÇÕES ELETROENCEFALOGRÁFICAS DURANTE A PRÁTICA DE MEDITAÇÃO MINDFULNESS

Guaraci Ken Tanaka

Orientadora: Bruna Brandão Velasques

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Aprovada por:

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Prof. Alair Pedro Ribeiro de Souza e Silva

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RESUMO

Mindfulness é o estado de atenção plena no presente momento de forma intencional com abertura e livre de julgamentos. A partir dessa definição clássica de mindfulness, muitos estudos vem trazendo fundamentos neurofisiológicos capazes de trazer explicações de como o processo atencional de mindfulness tem trazido tantos benefícios. Um dos aspectos principais que diferenciam Mindfulness de outros processos atencionais é o fato da forma como a atenção é dirigida. Esta atenção pode ser dividida como focada e como de monitoramento aberto. Os estudos tem apresentado esses tipos atencionais como características específicas relacionado ao tempo de prática, onde a atenção focada parece estar mais relacionada a praticantes iniciantes ou novatos e o monitoramento aberto ao praticantes com mais experiência. Com isso, esta dissertação tem o objetivo de apresentar as alterações eletrofisiológicas entre meditadores novatos e avançados antes, durante e depois da prática de monitoramento aberto. Para isso, foram analisados bandas de baixa e alta frequência em busca de traços capazes de explicar as alterações fisiológicas dos meditadores experientes. A maioria dos estudos tem analisados bandas de baixa frequência por associar a prática de mindfulness com relaxamento. Ao analisar a banda teta e alfa na região frontal foram observados uma menor atividade para meditadores avançados em relação a novatos, demonstrando um menor esforço na realização da prática, o que parece ser um traço específico de meditadores avançados, pelo fato, de uma melhor performance atencional promover uma menor atividade cortical. Este fato também se deu na banda de alta frequência beta, apesar dessa banda não apresentar grandes diferenças quando analisadas numa meta-análise. Já a banda gama, tem uma relação bem específica para meditadores avançados e por isso, foi analisado uma correlação entre as áreas frontais e parietais, visto que essa rede tem uma relação direta com processamentos cognitivos. Desta forma, meditadores avançados tendem a ter uma maior coerência fronto-parietal mesmo com uma diminuição durante o monitoramento aberto quando comparado com os meditadores novatos. A meditação é uma prática capaz de potencializar os efeitos benéficos da atenção, visto que seu objetivo é a elaboração de pensamentos sem ruminação ou qualquer envolvimento emocional, tornando melhor e mais rápido a resposta de novos estímulos, gerando um aumento na concentração e aprendizado.

Palavras chaves: Mindfulness; monitoramento aberto; atenção; EEG

ABSTRACT

Mindfulness is a state of attention in the present moment with openess and intention without judgment. Based on this classic definition, many researches are developing the neurophysiologic concepts to explain how the attentional processing of mindfulness regarding the benefits. An important point which shows the differences between mindfulness and others attentional process is related to how the pathway of this attention is directed. Mindfulness is divided in focused attention and open monitoring. Focused attention strict attention in a specific object (i.e. body, breathing) and open monitoring is the maintenance of attention in every stimulus to come from. Some researchers have shown these styles of mindfulness associated with time of practice as beginner is related to focused attention and open monitoring for long-term. Probably, it is a specific attention trait for trained practitioner. The aim of this work is evaluate the electrophysiological differences between novice and experienced meditator before, during and after an open monitoring meditation. Most of these studies have shown an increase of low frequency (i.e. alpha, theta) activity during focused attention, particularly in the alpha band. This band also associated with a relaxation pattern and some studies showed this difference. These low frequencies in the frontal brain area was associated with improve attention related to executive attention (i.e. working memory). Our hypothesis is the experienced meditator has a specific trait associated with low cognitive activity in the frontal area during open monitoring. Another finding is related to high frequency bands (i.e. beta, gamma) which we suppose that is associated with experience. Despite a lack of studies in this band, some authors have found high frequency in the posterior lobes, as parietal and occipital, and it is associated with perception of the attention, as a conscious of awareness. We hypothesized that gamma frequency in the fronto-parietal network is the biomarker for experienced meditator due to low frontal activity to sustain the attention. This trait works as a neural efficiency to meditate in the same way of the novice.

Key-words: Mindfulness; open monitoring; attention; EEG

SUMÁRIO

CAPÍTULO 1 – O Problema

1.1 Introdução

A origem da meditação está baseada em fontes com um conceito filosófico oriental de mais de 2500 anos, muitas vezes com uma conotação religiosa e mística, prejudicando o desenvolvimento científico no ocidente (MOGRABI, 2011) e dificultando o entendimento fisiológico que era proporcionado na época. Não obstante, vários artigos e livros foram publicados a partir de meados do século passado demonstrando propostas diferentes e relevantes (AUSTIN, 1999; DAVIDSON; GOLEMAN; SCHWARTZ, 1976; DEIKMAN, 1963; FISCHER, 1971; KABAT-ZINN; LIPWORTH; BURNEY, 1985; WEST, 1987), e com o desenvolvimento das técnicas de mapeamento cerebral com eletroencefalografia (EEG) e neuroimagem, foi possível investigar os mecanismos neurofisiológicos pelo qual a meditação exerce seus efeitos.

Todavia, os estudos de meditação sofrem alguns problemas como: a falta de dados estatísticos e população de controle, heterogeneidade dos estados meditativos, a dificuldade no controle do grau de especialização dos praticantes e a ausência de uma definição clara sobre a meditação e seus subtipos (CHIESA; SERRETTI, 2010; TANG; HÖLZEL; POSNER, 2015). Este estudo se baseia nas concepções neurocientíficas modernas, e que se diferenciam pela forma como a atenção é dirigida: monitoramento aberto (MA) e meditação de atenção focada (AF) (CAHN; POLICH, 2006; KABAT-ZINN; LIPWORTH; BURNEY, 1985; MANNA et al., 2010; PERLMAN et al., 2010).

A primeira exige a manutenção da atenção em um estado de percepção aberto, atento momento a momento a qualquer sensação, pensamento ou sentimento; e a última requer o estreitamento do foco de atenção em um objeto pré-selecionado (LUTZ et al., 2008). A partir do momento em que os mecanismos neurofisiológicos destes dois subtipos de prática do Mindfulness foram se esclarecendo, novos problemas metodológicos foram encontrados. Com isso, a necessidade de expor a técnica usada durante os experimentos se tornou essencial, tendo em vista diferentes vias neurológicas bem específicas (CHIESA; SERRETTI; JAKOBSEN, 2013).

O relativo impacto da meditação sobre as diferentes frequências de atividade cerebral ainda não é bem entendido, e provavelmente esse impacto varia de acordo com a técnica meditativa e o tempo de prática. Estados mentais relacionados à prática de meditação em um nível iniciante foram frequentemente correlacionados com um aumento da potência e sincronização da atividade de baixa frequência, em particular, oscilações alfa e teta (Fell et al. 2010; Gaylord C, Orme-Johnson D 1989; Kubota et al. 2001; Takahashi et al. 2005; Travis 1991). Tais alterações são bastante inespecíficas, porque são observadas em diferentes técnicas de meditação, e também durante o relaxamento e a transição ao estado de sono. Nesses casos, observa-se um aumento de teta na região frontal, porém durante tarefas relacionadas à meditação esse aumento ocorre devido frequências na banda teta estarem relacionados a processos atencionais específicos como memória de trabalho (ITTHIPURIPAT; WESSEL; ARON, 2013; SAUSENG et al., 2010).

Lagopoulos et al (2009) comparou uma prática de 20 minutos de meditação de monitoramento aberto (sem um objeto de foco) com um estado de 20 minutos de repouso e verificou que durante o processo meditativo apresentou um aumento tanto em teta (áreas frontais) quanto em alfa (áreas posteriores) quando comparados com o repouso. Com isso, pode se concluir que esse resultado está relacionado ao processo atencional específico da meditação, visto que a banda alfa tende a aumentar quando ocorre uma diminuição na atividade cortical (DEL PERCIO et al., 2009), demonstrando um menor esforço atencional (SAGGAR et al., 2012). Por outro lado, teta na região fronto-medial foi associada ao estado concentrado de atenção e ao processamento da memória e emoções (FELL; AXMACHER; HAUPT, 2010; KOVACEVIC et al., 2012), sendo verificado tanto em praticantes novos que permanecem concentrados em um objeto específico, como em meditadores mais experientes de mindfulness. Os escassos dados empíricos de praticantes experientes indicam que os estados mentais alcançados por estes implicam tanto o aumento da potência e sincronização dos ritmos lentos (SAGGAR et al., 2012), como um aumento da potência e sincronização das oscilações gamma em torno de 40 Hz (BERKOVICH-OHANA; GLICKSOHN; GOLDSTEIN, 2012; CAHN; DELORME; POLICH, 2010; YERAGANI et al., 2006).

Estudos que investigam alta frequência (i.e., beta e gama) e mindfulness ainda são escassos. Os primeiros estudos que investigaram ativações gama em meditadores apresentaram grandes problemas metodológicos (FELL; AXMACHER; HAUPT, 2010). Apesar disso, as hipóteses em relação a atividades gama em meditadores parecem ter fundamentação robusta. (BERKOVICH-OHANA; GLICKSOHN; GOLDSTEIN, 2012; FERRARELLI et al., 2013; LUTZ et al., 2004). Uma dessas hipóteses acredita que as oscilações em gama (30-80 Hz) tenham um papel crucial no processamento integrado das redes neurais possibilitando uma maior percepção consciente do estado atual (MEADOR et al., 2002) tanto em meditadores avançados realizando atenção focada (HINTERBERGER et al., 2014) quanto nos casos de monitoramento aberto (LUTZ et al., 2004).

Corroborando a essa ideia, um estudo de Jo e colaboradores (2015) demonstraram que meditadores avançados percebem a intenção de um movimento voluntário de forma diferente de não meditadores, concluindo que meditadores avançados conseguem ampliar sua percepção antes mesmo de executar um movimento voluntário (JO et al., 2015). A aparição deste padrão oscilatório em frequências acima de 30 Hz, com uma maior intensidade à medida que a meditação progride, sugere uma mudança na 'qualidade da consciência' (CHIESA; SERRETTI; JAKOBSEN, 2013). Neste sentido, esse padrão dá lugar a um estado de atenção máxima com um mínimo gasto energético, o que implica, por sua vez, uma maior sensibilidade perceptiva, ainda que menos emocionalmente reativa. Neste sentido, alguns autores têm apresentado que a meditação mindfulness, principal prática entre meditadores experientes, induz a um aumento da atividade e sincronização de gama (BERKOVICH-OHANA; GLICKSOHN; GOLDSTEIN, 2012; FERRARELLI et al., 2013; HAUSWALD et al., 2015).

1.3 Justificativa

Apesar de um grande número de estudos e propostas teóricas, estudos de meditação de monitoramento aberto não são muito bem definidos devido à heterogeneidade dos estados meditativos estudados. Além disso, os grupos controles realizam tarefas diferentes, como relaxamento ou apenas estar atento. Desta forma, os resultados propostos não comparam igualmente a tarefa e contribuem para o limitado conhecimento atual acerca da neurofisiologia da meditação entre meditadores iniciantes e avançados. Esta dissertação pretende oferecer uma avaliação dentro dessa lacuna, relacionados ao tempo de prática, bem como uma classificação neurofisiológica dos dois grupos a serem estudados (i.e., meditadores experientes *versus* não meditadores). Além disso, os dois tipos de mindfulness (atenção focada e monitoramento aberto) não tem sido bem diferenciados. Os diferentes padrões neurofisiológicos de cada tipo de mindfulness produzem diferentes efeitos bem específicos e devem ser analisados de forma distinta. Os estudos vêm sendo baseados numa atenção mais focada onde atividades mais cognitivas são exploradas, porém processos neurofisiológicos de monitoramento aberto tem uma característica mais relacionada a meditadores avançados e que apresentam uma melhor eficiência neural, propiciando uma menor atividade cognitiva para a manutenção da atenção.

1.4 Objetivos

O presente estudo teve como foco investigar as alterações na atividade elétrica cortical durante a prática de monitoramento aberto de meditadores experientes e novatos. Em especial, serão apresentados três artigos que examinaram diferentes aspectos eletrofisiológicos associados à prática de monitoramento aberto comparando dois grupos diferentes. Sendo assim, nossos objetivos específicos são:

- Investigar os aspectos Relevantes da Banda Teta na Região Frontal na Prática de Monitoramento Aberto de Mindfulness;
- Analisar aspectos do processo Atencional da Banda Beta na prática de Monitoramento Aberto de Mindfulness;
- Avaliar a rede Fronto-Parietal nos praticantes experientes.

1.5 Hipótese

A presente dissertação tem como hipótese que o tempo de prática e a técnica utilizada produzem diferentes padrões eletrocorticais que podem estar relacionados a processos distintos de regulação atencional específicos a cada etapa de prática.

CAPÍTULO 2

2.1 O que é Mindfulness?

> "Mindfulness é a capacidade de focarmos nossa atenção intencionalmente na experiência direta do momento presente, numa atitude aberta e não-julgadora" – Jon Kabat-Zinn

O Treinamento mental baseado em mindfulness proporciona o desenvolvimento do processo cognitivo geral através de um modelo específico de aprendizado. (LUTZ et al., 2009; SLAGTER; DAVIDSON; LUTZ, 2011). Os maiores avanços nos estudos de mindfulness ocorreram após as pesquisas de neuroimagem mostrarem alterações corticais e sub-corticais importantes decorrentes da prática de mindfulness de longo prazo. Um dos principais foi o estudo da Sara Lazar (2005), mostrando que a prática ao longo da vida tem a capacidade de gerar um aumento de espessura no córtex pré-frontal e na ínsula quando comparados com não praticantes de mesma idade (LAZAR et al., 2005). Corroborando com esses achados, os estudos de Richard Davidson, que avaliou monges budistas, ou seja, praticantes avançados com prática regular de mais de 20 anos, também encontrou evidências de alterações corticais importantes, como uma maior atividade no córtex dorso-lateral pré-frontal, córtex cingulado anterior e ínsula relacionados ao tempo na prática de meditação (DAVIDSON et al., 1990, 2003; DAVIDSON; MCEWEN, 2012). Essas regiões tem uma função cognitiva específica de processos atencionais, assim como uma ativação correspondente a uma maior consciência desse processo atencional. O processo intencional de como a atenção é dirigida parece ser uma característica relacionada ao treinamento e que são observados em meditadores experientes, porém estudos com monitoramento aberto precisam ser realizados para entender os processos neurofisiológicos neste tipo de meditação que parece estar mais associado com processos de melhor eficiência neural.

Neste contexto, a prática de mindfulness parece ter um papel importante tanto na detecção das distrações como no direcionamento atencional (MALINOWSKI, 2013). Todo esse processo possui diferentes padrões neurofuncionais ativando regiões específicas, demonstrando que a prática de mindfulness está muito além de apenas treinar a atenção (HASENKAMP et al., 2012). Desta forma, mindfulness está mais vinculado a um padrão de conscientização das experiências do momento presente, incluindo as percepções das sensações, pensamentos, emoções, sons sem nenhum tipo de julgamento com abertura e intenção (KABAT-ZINN; LIPWORTH; BURNEY, 1985; MURAKAMI et al., 2012). Com isso, mindfulness pode ser dividido em dois processos atencionais: atenção focada e monitoramento aberto (LUTZ et al., 2008). Na atenção focada, um objeto prévio servirá de âncora para manutenção da atenção, ou seja, o foco deve ser o objeto e toda vez que se distrai, simplesmente retorna-se a ele. Segundo Malinowski (2013), esse processo atencional focado possui características específicas desde os eventos distratores até o direcionamento ao objeto da atenção, sendo que nesse ínterim, processos como percepção da distração, engajamento e direcionamento da atenção acontecem ativando áreas diferentes do cérebro.

Já na prática de monitoramento aberto, não existe um objeto prévio para a manutenção da atenção, ou seja, todos os estímulos que surgem se tornam objeto de atenção como experiências sensoriais. Desta forma, existe uma atitude de abertura e maior flexibilidade cognitiva, proporcionando um aumento na criatividade (COLZATO; OZTURK; HOMMEL, 2012) que também pode acontecer na atenção focada, porém, por outra via neuronal (CAPURSO; FABBRO; CRESCENTINI, 2014). O que se percebe é que a forma como a atenção é direcionada depende do tempo de prática, sendo que os iniciantes tendem a uma atenção mais focada, enquanto os mais experientes tendem ao monitoramento aberto (CHIESA; SERRETTI; JAKOBSEN, 2013). A grande maioria dos estudos tem sido realizada com práticas de atenção focada, não levando em consideração a prática de monitoramento aberto. Porém, a prática da atenção focada facilita a percepção do momento da distração, uma vez que se tem um objeto específico para manter a atenção (i.e. corpo, respiração).

Esse momento de distração ativa áreas que formam uma rede neuronal conhecida como *Default Mode Network* (DMN) e está associado ao momento de devaneio ou de auto-reflexão (HASENKAMP et al., 2012). A ativação envolveas regiões do córtex pré-frontal medial, córtex cingulado posterior, córtex parietal inferior e junção temporo-parietal e precúneo (BREWER et al., 2011). A relação entre as redes neurais da atenção e a DMN parece ser um ponto importante para explicar os benefícios de mindfulness. Além disso, um dos aspectos importantes da atenção é a capacidade de perceber as distrações ou devaneios que são as possíveis causas desse processo de ativação do DMN. Com isso, ocorre a diminuição da vigilância aumentando os processos reativos a experiência (ex. pensamentos, julgamentos, emoções) (DEYO et al., 2009; TANAKA et al., 2014). Estudos de mindfulness têm mostrado alterações neurofisiológicas nessas redes à medida que o praticante vai se tornando mais experiente, proporcionando uma reorganização funcional mesmo fora da meditação (BERKOVICH-OHANA; GLICKSOHN; GOLDSTEIN, 2014; BREWER et al., 2011; TAYLOR et al., 2013). Consequentemente, a

DMN parece estar mais dirigida a um mau funcionamento do que simplesmente uma ativação dessa rede. Isso se deve ao fato de meditadores avançados apresentarem ativações nessas regiões sem estar vinculado a um problema. Ainda existe a necessidade de mais estudos que façam a correlação entre as redes de modo padrão e as atencionais promovidas por mindfulness, porém a forma como a atenção é dirigida tem influência nessa rede.

Apesar disso, alguns estudos estão direcionando melhor as metodologias sobre os tipos de meditação, o que é de suma importância, visto as diferenças neurofisiológicas entre elas. Sendo assim, a prática de monitoramento aberto demonstra ser um padrão de meditadores mais experientes e com isso trazendo uma maior qualidade atencional de forma mais ampla. Um dos fatores que corroboram com isso é o fato de uma menor atividade cortical gerar uma melhor conexão entre as regiões com uma maior eficiência neural (VAGO, 2014), como mostram estudos que apresentam uma menor atividade frontal durante a prática de monitoramento aberto (TANAKA et al., 2014, 2015). Essa menor atividade frontal está relacionada a um processamento cerebral mais eficiente, no qual se exige um menor esforço cognitivo para se manter o processo atencional. Isso acontece devido a atenção não ter um objeto específico, direcionando a atenção para as sensações e experiências que surgem (DELGADO et al., 2015).

As evidências mostram que a forma como a atenção é direcionada influenciam os iniciantes, que tendem a uma atividade mais associada a atenção focada e à medida que vai se desenvolvendo, é possível acessar vias cerebrais mais relacionadas com o monitoramento aberto (CHIESA; SERRETTI; JAKOBSEN, 2013). Essas alterações podem ser observadas em estudos transversais que comparam meditadores avançados e novatos. Na meta-análise proposta por Fox et al (2014), foram encontradas alterações, com um tamanho de efeito médio, em áreas relacionadas a meta-cognição (i.e. córtex frontopolar), consciência intero e exteroceptiva do corpo (i.e. córtex sensorial e ínsula), memória (i.e. hipocampo), auto-regulação emocional (i.e. córtex cingulado anterior e médio e córtex órbitofrontal) e na comunicação inter- e intra-hemisférica (i.e. fascículo longitudinal superior e corpo caloso) (FOX et al., 2014).

De um modo geral, os estudos não estão levando em consideração o efeito específico de como a atenção é direcionada. Numa revisão coordenada por Michael Posner (2015), foram apresentadas limitações em relação a qualidade metodológica e critérios que devem ser levados em consideração nos novos estudos como o efeito neurofisiológico de mindfulness a longo prazo através de estudos longitudinais mais longos (TANG; HÖLZEL; POSNER, 2015). Apesar disso, parece que o efeito do treinamento de forma aguda tem uma relação com o efeito neurofisiológico de mindfulness a longo prazo (CHIESA; CALATI; SERRETTI, 2011; CHIESA; SERRETTI; JAKOBSEN, 2013; CHIESA; SERRETTI, 2010; FERRARE LLI et al., 2013). Isso se deve ao fato de meditadores novatos terem uma tendência em direcionar a atenção de forma mais específica (atenção focada) e o treinamento amplia o processo atencional, sustentando o mesmo padrão atencional sem a necessidade de fixar a atenção em um objeto específico. Desta forma, mindfulness parece estar mais relacionado a esse desenvolvimento atencional de monitoramento aberto do que simplesmente uma prática atencional.

2.2 Aspectos atencionais de Mindfulness com base no EEG

> "A atenção funciona como uma orquestração de três redes distintas, consolidando achados comportamentais, genéticos e de imagens em um todo coerente" – Michael Posner

O processo atencional parece ser uma necessidade biológica de funcionalidade, pois ela consolida outras funções cognitivas necessárias para a realização de um objetivo. Em vista disso, um treinamento específico pode estabelecer o desenvolvimento de redes neurais melhorando a performance através do aprendizado (POSNER, ROTHBART e TANG, 2015). Apesar disso, cada vez mais necessitamos realizar várias tarefas simultaneamente, ou seja, o processo atencional acaba sendo direcionado continuamente para um novo foco. Esse processo atencional multitarefa exige o desenvolvimento de redes cerebrais relacionadas às funções para conseguir um estado de alerta orientando eventos sensoriais e desenvolvendo autocontrole (ROTHBART; POSNER, 2015). A forma como a atenção funciona tem sido tema de muitas pesquisas devido ao amplo efeito nas funções cognitivas. Afinal, alguns distúrbios cognitivos tem tido resultados satisfatórios em funções de atividades que envolvem a atenção como exercícios aeróbicos e treinamentos meditativos (BARTLEY; HAY; BLOCH, 2013; GOYAL et al., 2014; TANG; POSNER, 2009). O processo na habilidade atencional depende da capacidade de mudar do estímulo a tarefa enquanto mantém o simples foco entre as distrações (ROTHBART; POSNER, 2015).

Embora alguns estudos demonstrem uma maior atividade cortical focada com uma diminuição na atividade mais global (DA ROCHA; ROCHA; MASSAD, 2011), outros tem apresentado um menor recrutamento neural para exercer determinadas funções (GIRGES et al., 2014; TANAKA et al., 2014). Com isso, hipotetizamos que a prática de monitoramento aberto tem a característica neural mais eficiente. A maioria dos estudos tem utilizado a ressonância magnética funcional e tomografia computadorizada para investigar os processos neurofisiológicos de Mindfulness. Estas técnicas têm como principal vantagem a alta resolução espacial, avaliando com maior precisão a localização das atividades nas estruturas cerebrais. Desta forma, os principais achados são encontrados em meditadores experientes que demonstram diferenças de ativação quando comparados com meditadores iniciantes ou novatos em áreas como córtex pré-frontal dorso lateral, córtex cingulado anterior, ínsula, precúnio, junção temporo-parietal (CHIESA, 2010; HAKAMATA et al., 2013; HÖLZEL et al., 2011; MOULTON et al., 2012). Essas áreas estão relacionadas a um melhor desempenho atencional e auto-regulação emocional (TANG; HÖLZEL; POSNER, 2015). Além disso, é possível observar mudanças estruturais da substância cinzenta em áreas como ínsula e córtex pré frontal de praticantes idosos comparados a um grupo de não praticante, demonstrando um efeito benéfico a longo prazo (LAZAR et al., 2005).

Recentemente tem se verificado o aumento de estudos que utilizam a eletroencefalografia para investigar os processos de atenção e a prática de Mindfulness. O eletroencefalograma, apesar de sua baixa resolução espacial, possui uma alta resolução temporal, sendo uma ferramenta bastante utilizada para verificar os efeitos temporais de tarefas que envolvem aspectos cognitivos e atencionais (BASILE et al., 2013; BITTENCOURT et al., 2012; VELASQUES et al., 2011). As análises dos sinais de EEG podem ser uma excelente ferramenta para avaliação da performance cognitiva e eficiência neural. Essas análises transformam os sinais das ondas eletroencefalográficas em dados quantitativos, através de um método de análise espectral, informando a amplitude das bandas de frequência separadamente.

Esse processo é realizado através de um cálculo matemático e é conhecido como Transformada de Fourier. Este cálculo possibilita analisar diferentes amplitudes dentro de um período de tempo (1 segundo ou mais). A partir disso, um novo cálculo, conhecido como Transformada Rápida de Fourier, é realizado para decompor as atividades do EEG para gerar o domínio da frequência (VELASQUES et al., 2011, 2013). Essa frequência pode ser dividida em bandas específicas de baixa frequência (i.e. delta, teta e alfa) e alta frequência (i.e. beta e gama). Outro método de análise é o potencial relacionado ao evento e representam o resultado promediado da atividade elétrica a cada instante, dentro de um intervalo de tempo fixo após um estímulo. Assim é possível caracterizar um comportamento eletrofisiológico exclusivo do estímulo (BOSTANOV et al., 2012; HO et al., 2015; HOWELLS et al., 2014). Além disso, também é possível verificar como essas frequências interagem nas diferentes áreas corticais através das análises de potência absoluta, potência relativa, assimetria e coerência.

Um dos aspectos que tem sido discutido é o fato dos mecanismos neurais ainda não estarem claros e a necessidade de métodos mais rigorosos durante as mudanças dos padrões (traços e estados) proporcionados pela prática regular de Mindfulness (TANG; HÖLZEL; POSNER, 2015). Desta forma, o EEG parece ser uma ferramenta essencial de análise tendo em vista que ela é uma excelente técnica com ótima resolução temporal. Nos estudos iniciais eram analisadas bandas de frequência baixa (ex: delta, teta e alfa), pois se acreditava que a meditação estava relacionada a um padrão de relaxamento

(FELL; AXMACHER; HAUPT, 2010). Estes estudos são os mais encontrados, visto que a prática tende a uma diminuição no ritmo biológico (DITTO; ECLACHE; GOLDMAN, 2006; FJORBACK et al., 2013; TAKAHASHI et al., 2005) devido a ativação parassimpática (DITTO; ECLACHE; GOLDMAN, 2006).

Alguns estudos têm realizado comparações entre mindfulness e relaxamento, a fim de demonstrar suas diferenças. Os resultados apresentam diferenças tanto no potencial evocado (LAKEY; BERRY; SELLERS, 2011) quanto relacionado às bandas de frequência (LAGOPOULOS et al., 2009), mostrando que as práticas de mindfulness têm características eletrofisiológicas bem diferentes de um simples relaxamento, assim como na resolução de conflitos e manejo do stress (DUNN; HARTIGAN; MIKULAS, 1999; FAN et al., 2015). Em uma revisão sistemática sobre padrões eletroencefalográficos, foram encontrados um aumento nas potências alfa e teta durante a meditação comparada ao repouso de olhos fechados e que estão relacionados a uma atenção relaxada proporcionando saúde mental (LOMAS; IVTZAN; FU, 2015). Apesar desses estudos apresentarem diferenças significativas do grupo controle, ainda fica limitado o entendimento neurofisiológico de como a prática de mindfulness se desenvolve ao longo do tempo, visto que baixas frequências estão associadas a inúmeros processos mentais diferentes de mindfulness.

Apesar disso, a manutenção da atenção focada nas sensações do corpo (i.e. respiração, partes do corpo) tende a promover uma auto-regulação cognitiva, aumentando ritmos alfa nas áreas do córtex somatossensorial primário, de forma que processos reativos (i.e. ruminação, reação a dor) possam ser filtrados a ponto de se organizar um fluxo de informações sensoriais no cérebro (KERR et al., 2013). Á medida que essa prática vai se desenvolvendo, esta manutenção vai se tornando cada vez mais fácil e a percepção dos processos distrativos que geram ações reativas, cada vez mais vão se potencializando. Estudos de assimetria frontal alfa, têm apresentado resultados contundentes sobre as mudanças de comportamento em relação aos processos reativos, onde a assimetria alfa à esquerda na região frontal proporciona situações mais positivas, menos reatividade (CHAN; HAN; CHEUNG, 2008; COAN; ALLEN; HARMON-JONES, 2001), auto-regulação emocional (DAVIDSON, 1992; DAVIDSON et al., 1990) e tem sido correlacionado como um traço de mindfulness (SCHOENBERG et al., 2014).

Apesar da banda alfa apresentar uma relação com eficiência neural no processo atencional de meditadores, as frequências mais altas, como gama, parecem justificar melhor processos relacionados aos efeitos benéficos tardios de mindfulness (FERRARELLI et al., 2013). Sendo assim, devido a escassez de estudos de alta frequência quando comparadas com as de baixa frequência, novos estudos começaram a ser realizados com bandas de alta frequência como beta e gama. Estudos na banda beta não vem apresentando resultados significativos relacionados ao processo de atenção de mindfulness quando vista numa meta-analise (LOMAS; IVTZAN; FU, 2015), já que a banda beta é melhor visto em processos atencionais de integração sensório-motora (BASILE et al., 2013; FORTUNA et al., 2013; SILVA et al., 2012), apesar de um estudo prévio, que não fez parte desta meta-análise, mostrar diferenças significativas relacionadas a uma menor atividade frontal beta de meditadores experientes quando comparados a meditadores novatos (TANAKA et al., 2015). Já a banda gama tem mostrado ser uma excelente frequência para observar os padrões neuronais de meditadores avançados, tendo em vista, diferenças robustas quando comparados com meditadores novatos e/ou iniciantes (CAHN; DELORME; POLICH, 2010; LUTZ et al., 2004). Neste caso, gama estaria relacionada à percepção da consciência envolvendo uma maior percepção e sensibilidade na clareza da consciência da experiência do momento presente somada a uma diminuição de reações automatizadas (CAHN; DELORME; POLICH, 2012; LUTZ et al., 2004).

De um modo geral, a prática regular de mindfulness promove alterações importantes no funcionamento cerebral de forma que ele se torne mais eficiente diante da manutenção da atenção e percepção dos devaneios. As atividades frontais se tornam mais sincronizadas (ZANESCO et al., 2013) e com menos esforço (TANAKA et al., 2015). No estudo de Berkovich-Ohana e colaboradores (2014), foram apresentados resultados relacionados a um melhor desempenho na conectividade neural durante a meditação mindfulness diminuindo atividades em áreas relacionadas a devaneio e ruminação, conhecida como rede de modo padrão. Neste estudo foi observada a conectividade funcional através do eletroencefalograma, usando um índice de média de coerência de fase (MCF), para verificar a distribuição relativa da conexão das redes neurais relacionadas aos processos de atenção. A atividade na rede de modo padrão (devaneio) foi reduzida quando analisada a MFC da banda gama inter-hemisférica durante a transição do repouso para a tarefa, especificamente existiu uma redução relativa na MCF teta à direita e MCF alfa e gama à esquerda. A MCF gama parece ser um traço de atenção dos meditadores, visto que reduziu a atividade da rede de modo padrão e esta se refere ao devaneio. Essa atividade gama de meditadores experientes parece transpassar os efeitos benéficos da atenção (BLACK et al., 2015), pois também possui uma atuação na privação de sono, ou seja, meditadores experientes com mais de 15 anos de prática regular apresentam ondas gama durante o sono NREM nas áreas parieto-occiptais como uma característica do treinamento de longo prazo (DENTICO et al., 2016; FERRARELLI et al., 2013).

Sendo assim, estudos de mindfulness com EEG tende a explicar melhor como as alterações corticais, vistas nos estudos de neuroimagem, acontecem. A análise temporal do EEG mostra os efeitos da prática relacionados a algum evento cognitivo ou ao longo do tempo. Isso é reforçado quando estudos utilizando programas de EEG que localizam a fonte de energia que chegam aos eletrodos (i.e. LORETA) apresentam as mesmas regiões dos estudos de neuroimagem (BROWN; JONES, 2010; CAHN; POLICH, 2006). Essa análise temporal fornece informações que ainda são escassas referentes ao efeito da prática ao longo do tempo (TANG; HÖLZEL; POSNER, 2015). A dificuldade desse tipo de estudo, se dá pelo fato dos achados mais relevantes estarem relacionados a meditadores avançados com mais de 20 anos e 10.000 horas de prática. Um estudo longitudinal nesse caso demanda tempo e um exaustivo controle das variáveis que podem trazer efeitos causais. Porém, mudanças neurofisiológicas e estruturais já podem ser observadas no final de um treinamento de 8 semanas e com um acompanhamento após 24 meses (KUYKEN et al., 2015). Ainda assim, estudos transversais comparando meditadores avançados com não meditadores, trazem resultados importantes para o entendimento neurofisiológico da meditação. Com base nisso, estudos utilizando EEG tem sido mais usados ultimamente, demonstrando não só atividades de baixa frequência em meditadores avançados, mas também, frequências acima de 30 Hz (i.e. gama) que podem estar relacionadas com os benefícios encontrados após o treinamento, não apenas de forma aguda, mas de forma mais consolidada (CAHN; DELORME; POLICH, 2010).

Diferenças podem ser observadas desde meditadores iniciantes até os avançados através de análises transversais, possibilitando diferenças específicas de acordo com o tempo de prática. De um modo geral, meditadores iniciantes ou novatos tendem a um maior controle durante a prática de Mindfulness, o que pode ser demonstrado por uma maior atividade frontal (i.e. funções executivas) tanto baixa quanto de alta frequência durante a prática. Isso ocorre, pelo fato da necessidade de se manter o foco em um objeto percebendo os diferentes processos atencionais e das distrações (VAGO, 2014). Isso faz com que a integração cerebral na execução da tarefa tenha um maior direcionamento da região frontal para regiões mais posteriores (i.e. parietal). À medida que a atenção vai se tornando mais fácil ao longo do treinamento de Mindfulness, um aumento na percepção sobrepõe efeitos de controle para a manutenção da atenção e os processos atencionais se tornam muito mais sensorial e consciente (DELEVOYE-TURRELL; BOBINEAU, 2012), característico da prática de atenção mais ampla (i.e. monitoramento aberto), ou seja, sem a necessidade de se manter fixo a um objeto respeitando mais o fluxo do processamento atencional. Essa forma como a atenção é direcionada promove uma menor atividade cortical nas regiões frontais tanto de alta como baixa frequência, assim como um aumento de atividades de alta frequência, especificamente da banda gama, nas regiões mais posteriores.

CAPÍTULO 3 - METODOLOGIA

3.1. Participantes

Vinte e um participantes foram recrutados, dos quais onze meditadores experientes (ME) (7 homens, 43,8 ± 17,53 anos) e dez sujeitos controles (SC) (5 homens, 40,10 ± 14,72 anos) que nunca tinha meditado. O grupo de meditadores experientes inclui monges e leigos de várias tradições budistas, foram recrutados a partir de três grandes centros de meditação (ex: Zen, Kadampa e Vipassana), localizadas em torno da Universidade Federal do Rio de Janeiro (UFRJ). O grupo controle foi recrutado na UFRJ. Todos os participantes foram contatados duas semanas antes de iniciar a pesquisa. A condição para os meditadores era ser praticante regular, pelo menos, nos últimos cinco anos (12,23 anos de prática ± 7,65) e todos eles devem ser da mesma cidade, sob a mesma condição social e exposta ao mesmo estímulo ambiental (ie, não viver isolado em centros budistas) do grupo de controle. Todos os participantes estavam livres de medicação e não tinham déficits motor, cognitivos ou sensoriais que poderiam afetar seu desempenho na atenção. Os indivíduos deram seu consentimento por escrito (de acordo com a Declaração de Helsinki) para participar do estudo. O experimento foi aprovado pelo Comitê de Ética da Universidade Federal do Rio de Janeiro (IPUB / UFRJ).

3.2. Tarefa Experimental

Os indivíduos sentaram-se com a coluna reta, em uma sala escura e sem ruído para minimizar a interferência sensorial. Os indivíduos foram convidados a repousar durante 4 minutos (instruções de repouso foram objeto de especial ênfase para os ME, que deveriam abster-se para entrar no estado de meditação), e então eles começaram o monitoramento aberto por 40 minutos, para finalmente repousar por mais 4 minutos no final. Um sinal auditivo marcou o início e fim de cada fase.

As Instruções mindfulness para ME e SC foram: "prestar atenção a tudo o que entra em sua consciência. Seja um pensamento estressante, uma emoção ou sensação do corpo, basta deixá-lo passar de um modo fácil, sem tentar mantê-lo ou alterá-lo de qualquer maneira, até que algo mais chegue a sua consciência " (BREWER et al., 2011). Foram dadas instruções logo antes do início da prática, para promover uma melhor motivação no contato de uma prática nova. Devido à sua simplicidade, a técnica poderia ser aplicada facilmente, e nós consideramos isso como particularmente importante, uma vez que os indivíduos relataram não terem problemas para seguir as instruções.

3.3. Aquisição de Dados Eletroencefálicos

O Sistema internacional 10/20 de eletrodos do EEG (Jasper, 1958) foi usado com um sistema de EEG de 20 canais (Braintech-3000, a EMSA Instrumentos Médicos, Brasil). Os 20 eletrodos foram dispostos em uma touca de nylon (ElectroCap Inc., Fairfax, VA, EUA) produzindo derivação monopolar usando os lóbulos das orelhas como referência. A impedância dos eletrodos de EEG e EOG foi mantida entre 5-10 kW. A amplitude dos dados registrados era inferior a 70μV. O sinal EEG foi amplificado com um ganho de 22.000 Hz, analogicamente filtrados entre 0,01 Hz (passa-alta) e 80Hz (passa-baixa), e taxa de amostragem foi de 200 Hz. O software *Data Acquisition* (Delphi 5.0) do laboratório de Mapeamento Cerebral e Integração Sensório Motora foi empregado com o filtro digital de encaixe (60 Hz).

3.4. Análise de Dados

A análise dos dados foi realizada utilizando MATLAB 5.3 (Mathworks, Inc.) e a caixa de ferramentas do EEGLAB (http://sccn.ucsd.edu/eeglab). Nós aplicamos uma inspeção visual e a análise de componentes independentes (ICA, em inglês) para remover possíveis fontes de artefatos produzidos pela tarefa (ou seja, piscadas, músculos faciais). Os dados foram coletados utilizando a referência bi-auriculares e foram transformados (re-referenciados), utilizando a referência média e depois realizamos a eliminação artefato usando ICA.

3.5. Análise Estatística

Na análise estatística, uma ANOVA 2-way e um teste post hoc (Bonferroni) foram realizados para analisar o fator grupo (ME x SC) e momento (repouso inicial, meditação, repouso final) de coerência de gama para cada par de eletrodos individualmente.

CAPÍTULO 4 - ESTUDOS

Serão apresentados três artigos referentes a análise transversal entre meditadores experientes (>12 anos de prática) e não meditadores que nunca tiveram contato com a prática de Mindfulness. Particularmente, analisamos um tipo de prática conhecida como monitoramento aberto que estão relacionados a manter a atenção a tudo aquilo que surge na consciência (i.e. pensamentos, sensações, emoções) sem julgamentos e com abertura e intenção. Desta forma, este tipo de meditação tem características peculiares no processo de atenção, principalmente nas regiões do cérebro associadas a processos cognitivos. Com isso, os dois primeiros artigos analisaram a potência absoluta de teta e beta (baixa e alta frequência) na região frontal, tendo em vista, essas bandas refletirem bem o momento atencional. Já o terceiro artigo, avaliou a coerência gama na rede fronto-parietal, por ser uma rede que integra o sistema sensório-motor.

.O primeiro estudo ***Lower Trait Frontal Theta Activity in Mindfulness Meditators***, teve como objetivo investigar o papel da potência absoluta da banda teta antes, durante e depois a prática de monitoramento aberto da meditação Mindfulness. Esta questão foi abordada para investigar o mecanismo de funcionamento da potência teta no córtex frontal de meditadores experientes comparados com não meditadores. Com isso, vinte um sujeitos realizaram a tarefa sendo que onze deles eram praticantes experientes (i.e. monges e professores). Para isso, foram registrados os padrões de atividade cerebral usando a eletroencefalografia quantitativa (EEGq). Foi encontrada interação para grupo e momento nos eletrodos Fp1, Fp2, F8, F3, F4 e F7. O grande achado foi que apesar de ambos os grupos apresentarem um aumento da potência teta durante a prática de Mindfulness, os meditadores experientes tiveram uma menor potência quando comparados com os não meditadores. Sugerimos que este achado é um correlato neural da capacidade dos praticantes especialistas em limitar o processamento de informações desnecessárias e aumentar a conscientização sobre o conteúdo essencial da experiência presente.

Já o segundo estudo, denominado ***Effortless Attention as a Biomarker for Experienced Mindfulness Practitioners***, examinou se o mesmo padrão ocorre em bandas de alta frequência como no caso de beta. Sendo assim, onze meditadores experientes e dez não meditadores realizaram a meditação de monitoramento aberto por quarenta minutos, sendo que antes e depois fizeram um repouso de quatro minutos. Foi encontrada interação para grupo e momento nos eletrodos Fp1, F8, F3, Fz, F4 e F7. Apesar desta banda na região frontal estar relacionado ao processo atencional, os meditadores avançados novamente apresentaram uma potência menor que a dos não meditadores, sugerindo que a forma como o processamento atencional de ambos seja diferente. Em vista disso, consideramos a hipótese dos meditadores avançados apresentarem um padrão de menor atividade cortical pelo fato da via ser diferente dos não meditadores que dependem de uma memória de trabalho mais ativa para realizar a tarefa. Concluímos então que os meditadores avançados possuem uma eficiência das funções cognitivas mais desenvolvidas decorrentes da frequência e intensidade da prática.

O terceiro estudo denominado **Mindfulness as a non cognitive process for experienced meditators: a fronto-parietal gamma coherence**

analysis, avaliou a rede fronto-parietal que tem indícios de ser responsável pela integração sensório-motora, memória de trabalho, consciência da percepção visual, auto-narrativa. Com isso, tornou-se evidente o estudo desta rede durante a prática de monitoramento aberto, pelo fato dessa rede ser um possível biomarcador quando analisado em bandas de alta frequência como gama. Para analisar os mecanismos dessa rede na potência gama foi observada as diferenças entre onze meditadores experientes e dez controles que nunca tiveram contato com meditação antes, durante e depois a prática de monitoramento aberto. Foram encontradas interações no grupo e momento entre os pares Fp1-P3, F4-P4, F7-P3 e F8-P4. O grande achado deste estudo foi o fato de encontrarmos uma maior coerência gama na rede fronto-parietal nos meditadores experientes mesmo diminuindo durante a prática. Isso sugere que o tempo de prática regular promove um melhor acoplamento dessas áreas na potência gama à medida que a prática vai ser tornando cada vez mais habitual. Essa hipótese é baseada no fato de que durante a prática de monitoramento aberto, os meditadores experientes exercem uma menor atividade frontal em consequência de uma diminuição de suas funções executivas, diferente dos controles que exigem uma maior atividade, principalmente da memória de trabalho por conta da manutenção da prática.

4.1 ARTIGO I: **Lower Trait Frontal Theta Activity in Mindfulness Meditators**

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Lower trait frontal theta activity in mindfulness meditators

Reduzida atividade teta na região frontal em praticantes de meditação mindfulness

Guaraci Ken Tanaka[1], Caroline Peressutti[1,2], Silmar Teixeira[1,2], Mauricio Cagy[5], Roberto Piedade[1], Antonio Egídio Nardi[6,7], Pedro Ribeiro[1,2,3], Bruna Velasques[1,2,3,4]

1Institute of Psychiatry of the Federal University of Rio de Janeiro – Brain Mapping and Sensory Motor Integration – Rio de Janeiro RJ.
2Institute of Applied Neuroscience (INA) – Rio de Janeiro RJ.
3School of Physical Education of the Federal University of Rio de Janeiro (UFRJ) Bioscience Department – Rio de Janeiro RJ.
4Institute of Psychiatry of the Federal University of Rio de Janeiro – Neurophysiology and Neuropsychology of Attention – Rio de Janeiro RJ.
5Biomedical Engineering Program, of the Federal University of Rio de Janeiro (COPPE/UFRJ) - Rio de Janeiro RJ
6Institute of Psychiatry of the Federal University of Rio de Janeiro – Panic & Respiration Laboratory – Rio de Janeiro RJ.
7National Institute of Translational Medicine (INCT-TM).
Correspondence: Guaraci Tanaka – Avenida Venceslau Bras 71 – CEP: 22290-140 Botafogo – Rio de Janeiro RJ – Brazil. E-mail: acupunturatanaka@gmail.com
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Abstract

Acute and long-term effects of mindfulness meditation on theta-band activity are not clear. The aim of this study was to investigate frontal theta differences between long- and short-term mindfulness practitioners before, during, and after mindfulness meditation. Twenty participants were recruited, of which 10 were experienced Buddhist meditators. Despite an acute increase in the theta activity during meditation in both the groups, the meditators showed lower trait frontal theta activity. Therefore, we suggested that this finding is a neural correlate of the expert practitioners' ability to limit the processing of unnecessary information (e.g., discursive thought) and increase the awareness of the essential content of the present experience. In conclusion, acute changes in the theta band throughout meditation did not appear to be a specific correlate of mindfulness but were rather related to the concentration properties of the meditation. Notwithstanding, lower frontal theta activity appeared to be a trait of mindfulness practices.

Keywords: mindfulness, meditation, EEG, frontal theta power, working memory.

Resumo

Os efeitos agudos e de longo prazo da meditação mindfulness sobre a atividade da banda teta não são claros. O objetivo deste estudo foi investigar as diferenças da banda teta na região frontal entre praticantes de mindfulness iniciantes e experientes. Desta forma, vinte participantes foram recrutados (dez meditadores budistas experientes e dez não meditadores). Apesar do aumento agudo da atividade teta durante a meditação para ambos os grupos, os meditadores apresentaram uma menor potencia em ambas as condições. Sugerimos que este achado e um correlato neural da capacidade dos praticantes especialistas em limitar o processamento de informações desnecessárias e aumentar a conscientização sobre o conteúdo essencial da experiência presente. Em conclusão, as alterações agudas na banda teta durante a meditação devem estar relacionadas ao processo de concentração típico de qualquer técnica meditativa. No entanto, a atividade teta reduzida encontrada entre meditadores experientes de mindfulness parece ser uma característica desta pratica especifica.

Palavras-chave: mindfulness, meditação, EEG, teta frontal, memória de trabalho.

The physiology of meditation practices may depend on whether they involve concentrative mindfulness (CM) or open monitoring mindfulness (OM) as well as on the practitioner's expertise level. Experienced meditators are able to maintain the meditative state for a long time in an effortless way compared to beginners. Electroencephalographic (EEG) studies of CM have found increased activity in low-frequency bands (alpha and theta), which reflect relaxation and attentional focus, in many brain regions, including the frontal cortex1–3. However, in long-term OM meditators, an increase in occipital4 and frontoparietal gamma activity also occurs due to their improved sensory awareness4. Evidence from long-term practitioners has also shown increased low-frequency oscillations in conjunction with gamma5. Lutz et al.6 have found an increased ratio of gamma to slow oscillatory activity (4–13 Hz). However, the authors did not discuss if this increased ratio was related only to higher gamma or lower slow activity or both6. Some hypotheses have been suggested, such as frontal theta (FT) activity is more engaged in CM than OM4 as well as higher frontal alpha-1 power and coherence is associated with transcendental meditation, indicating effortless meditation3.

FT activity has been described in many nonspecific situations as states of concentration, focused attention, emotion, working memory, drowsiness, and REM sleep (lower theta, 4–6 Hz)1,5,7,8. Thus, the studies of the cognitive processes underlying FT have been extensive, although its functions in meditation are still not clear. The mental states that are related to the practice of meditation at the beginner and experienced levels have often been correlated with increased theta activity9. However, such changes are quite unspecific because they are observed in different techniques of meditation and relaxation and during the transition to a sleep state5. Specifically, an increased FT has been observed in CM10,11, and it was defined as a sustained focus on a specific preselected object.

In contrast, OM refers to a state of sustained attention to any thought, feeling, or sensation that arises in the mind, with an attitude of acceptance and nonjudgment11. These mindfulness properties are thought to improve self-regulation and stress management by allowing individuals to refrain from trying to control the content of the mind12,13. Over the last decades, mindfulness-related treatments, such as mindfulness based stress reduction14 and mindfulness-based cognitive therapy15, have been extensively researched and applied in different clinical and nonclinical populations with positive results. Notwithstanding, there is a lack of consistent reports on the regulatory mechanisms of theta oscillations in this specific meditation technique. Thus, the aim of this study was to investigate FT differences between experienced and first-time meditators before, during, and after OM. We hypothesized that long-term meditation practice would change the oscillatory pattern of the theta band in expert practitioners

Methods

Twenty participants were recruited. Ten were experienced meditators (4 men; mean ± standard deviation age, 49.25 ± 8.66), including monks and laymen from various Buddhist traditions, and ten were healthy controls (5 men; age, 41.38 ± 15.10) who never meditated. The meditators must have practiced regularly for at least the last five years (11.61 ± 7.40 years), and all of them must have been living in the same city under the same conditions as the control group. All of the participants were medication-free and had no sensory, motor, cognitive, or attention deficits that could affect their performance. The subjects gave their written consent (in accordance with the Helsinki Declaration) to participate in the study. The experiment was approved by the Ethics Committee of the Federal University of Rio de Janeiro (IPUB/UFRJ).

Task protocol

The subjects sat with straight spines in a darkened and noise-free room to minimize sensory interference. Two meditators and one nonmeditator chose to sit on cushions on the floor, while the other participants sat on chairs. The subjects were asked to rest for 4 min (rest instructions were particularly emphasized for the meditators in order that they refrain from entering the meditative state), and then both groups started OM for 40 min. Finally, they rested for more 4 min at the end. An auditory signal marked the beginning and end of each stage.

The mindfulness (OM) instruction for the meditative and non meditative practitioners was to “pay attention to whatever comes into your awareness. Whatever it is, a stressful thought, an emotion or body sensation, just let it pass in an effortless way, without trying to maintain it or change it in any way, until something else comes into your consciousness” 16. The instructions were given immediately before the recording, as we believed this would promote higher motivation as it was a first attempt of a new activity. Due to its simplicity, the technique could be implemented, and we actually found this was particularly important. The subjects were evaluated after the task, and they reported any problems following the instructions.

EEG recording

The International 10/20 EEG electrode system (Jasper, 1958) was used with a 20-channel EEG system (Braintech-3000, EMSA Medical Instruments, Brazil). The 20 electrodes were arranged on a nylon cap (ElectroCap Inc., Fairfax, VA, USA), which yielded monopolar derivation by using the earlobes as reference. The impedance of the EEG and electrooculography electrodes was kept between 5–10 kΩ. The amplitude of the recorded data was less than 70 μV. The EEG signal was amplified with a gain of 22,000 Hz, analogically filtered between 0.01 Hz (high-pass) and 80 Hz (low-pass), and sampled at 200 Hz. The software *Data Acquisition* (Delphi 5.0) from the Brain Mapping and Sensory Motor Integration Lab was employed with the notch (60 Hz) digital filter.

The data analysis was performed with MATLAB 5.3 (Mathworks, Inc.) and the EEGLAB toolbox (http://sccn.ucsd.edu/eeglab). We applied a visual inspection and Independent Component Analysis (ICA) to remove possible sources of artifacts that were produced by the task (i.e., blink, muscle). The data were collected with the bi-auricular reference, and they were transformed (re-referenced) with the average reference after we conducted artifact elimination with the ICA.

First, each of the trials (rest 1, meditation, rest 2) was divided into segments of 6,000 data points, which corresponded to 30-s blocks. Second, as the meditation trials lasted as long as 40 min, we chose to analyze eight blocks (4 min) corresponding to the moment between 30 and 34 min, which is consistent with the moment in which meditators recognize they are entering a deeper (concentrative) state. At that moment, we had 24 trials of 30-s blocks. A fast

Fourier transform method was used to obtain the mean power amplitudes in the theta (4–7.5 Hz) band. The number of samples was 6,000 (30 s × 200 Hz) with rectangular windowing. The absolute theta power was individually calculated on each lead every 4 s, thus totaling 7 excerpts for each block. Thus, the total data for each group was 1,680 (24 trials × 7 absolute power samples × 10 subjects). As the data was not normally distributed, a logarithmic transformation of log10 was used. Because the data did not achieve a nearly Gaussian distribution, we therefore checked it individually and decided to exclude 4 observations that showed a value above 2 times the standard deviation.

The statistical analyses of the spectral densities at the frontal sites were performed on each lead individually and averaged into a single measure of the left and right hemispheres. We used a two-way mixed design analysis of variance (group by condition) and posthoc tests with a Bonferroni correction for multiple comparisons. All of the univariate analysis of variance tests were assessed for violations of the sphericity assumption, and, when violated, they were corrected with the Huynh-Feldt method.

Results

There was a statistically significant interaction between group and condition on the absolute theta power for Fp1, Fp2, F8 ($p<0.001$), F3 ($p<0.015$), F4 ($p=0.033$), and F7 ($p=0.002$). For the simple main effects result, the groups differed during rest 1 for the Fp1, F3, F4, and F8 derivations, during the meditation for the Fp1, Fp2, F3, F4, and F7 derivations, and during rest 2 for the F3, F4, F7, and F8 derivations. The F7 activity was statistically significantly greater in the control group (nonmeditator) in all of the conditions, except for Fp1 during rest 1 (Tables 1 and 2).

Table 1: Statistical analyses of between groups effects.

Electrode	Between group
Fp1	Rest 1 F(1, 478) = 13.083, p<0.001 Meditation F(1, 458) = 16.916, p<0.001
Fp2	Meditation F(1,2.719)= 48.425, p<0.001
F3	Rest1 F(1,497)= 73.164, p<0.001 Meditation F(1,495)= 61.827, p<0.001 Rest 2 F(1,498)= 106.400, p<0.001
F4	Rest 1 F(1,498)= 56.954, p<0.001 Meditation F(1,494)= 68.035, p<0.001 Rest 2 F(1,493)= 90.399, p<0.001
F7	Meditation F(1,487)= 7.554, p<0.006 Rest 2 F(1,495)= 28.409, p<0.001
F8	Rest 1 F(1,491)= 7.522, p<0.006 Rest 2 F(1,497)= 36.423, p<0.001

Table 2: Absolute theta power (μV²/Hz) means for both groups in the three conditions

Between groups			
μV²/Hz	rest 1	meditation	rest 2
Fp1			
meditator	-0.085	-0.157	-0.167
control	-0.184	-0.07	-0.097
Fp2			
meditator	-0.062	-0.13	-0.12
control	-0.05	0.026	-0.081
F3			
meditator	-0.375	-0.279	-0.383
control	-0.142	-0.045	-0.09
F4			
meditator	-0.332	-0.226	-0.363
control	-0.126	0.017	-0.094
F7			
meditator	-0.11	-0.104	-0.225
control	-0.082	-0.038	-0.095
F8			
meditator	-0.164	-0.082	-0.229
control	-0.107	-0.053	-0.093

Within the meditator group (MG), FT power was statistically significantly greater during the meditation compared to rests 1 and 2 for the F3, F4, F7, and F8 derivations and significantly reduced during rest 2 compared to rest 1 for the Fp1, F7, and F8 derivations (Table 3 and Figure 1). Within the control group (NMG), the FT power was statistically significantly higher during the meditation compared to rest 1 for all of the derivations studied, although it remained unchanged after the meditation (rest 2) for the Fp1 and F8 derivations (Table 3 and Figure 1).

For the averaged measure of the frontal sites, there was a statistically significant interaction between group and condition on the absolute theta power for the right ($p<0.001$) and left ($p<0.001$) frontal hemispheres. For the simple main effects result, the groups differed at rest 1 ($p<0.001$), meditation ($p<0.001$), and rest 2 ($p<0.001$) for both hemispheres (Table 4). The FT activity was significantly greater in the control group (NMG) in all of the conditions (Table 5). Within the meditator group (MG), the FT power was significantly greater during meditation compared to rest 1 and 2 for the right hemisphere and only during rest 2 for the left side. Within the control group (NMG), the FT power was significantly greater during meditation compared to the rest conditions for both hemispheres. However, there was an increase in the theta activity on the left side during rest 2 compared to during rest 1 (Tables 5 and 6, and Figure 2).

Table 3: Statistical analyses of within groups effects

Electrodes	Within meditator group		Within control group	
Fp1	p<0.017	rest1 and meditation (p=0.092) meditation and rest2 (p=1.000) rest1 and rest2 (p=0.007)	p<0.001	rest1 and meditation (p<0.001) meditation and rest2 (p=0.463) rest1 and rest2 (p<0.001)
Fp2	P=0.057		p<0.001	rest1 and meditation (p<0.001) meditation and rest 2 (p<0.001) rest1 and rest2 (p=0.329)
F3	p<0.001	rest1 and rest2 (p =1.00) rest1 and meditation (p<0.001) meditation and rest 2 (p<0.001)	p<0.001	rest1 and meditation (p<0.001) meditation and rest 2 (p=0.013) rest1 and rest2 (p<0.001)
F4	p<0.001	rest1 and rest2 (p=0.214) rest1 and meditation (p<0.001) meditation and rest 2 (p<0.001)	p<0.001	rest1 and rest2 (p=0.057) rest1 and meditation (p<0.001) meditation and rest 2 (p<0.001)
F7	p<0.001	rest1 and meditation (p=1.00) rest1 and rest2 (p<0.001) meditation and rest 2 (p<0.001)	p<0.001	rest1 and rest2 (p=1.00) rest1 and meditation (p=0.039) meditation and rest 2 (p=0.004)
F8	p<0.001	rest1 and meditation (p <0.001) rest1 and rest2 (p=0.009) meditation and rest 2 (p<0.001)	p<0.004	rest1 and rest2 (p=1.00) meditation and rest 2 (p=0.056) rest1 and medit (p=0.006)

Discussion

The aim of this study was to investigate whether EEG differences existed in the absolute FT powers between experienced meditators (MG) and a control group (NMG) during normal rest and OM meditation. We reported consistent interactions between the group and condition for almost all of the derivations, indicating that the level of meditation expertise (first-time vs. long-term meditators) had a differential effect on the FT power depending on the condition (rest 1 vs. meditation vs. rest 2). Our main findings will be discussed below.

An increase in FT power during meditation has been found in many studies10,17, thus supporting our findings of an increase in FT in both groups in the meditative state. The theta band in the frontal area has been associated with states of concentration, which is part of OM meditation practice. During OM, the attention is involuntary and directed to any stimulus that arises in the field of perception at any given moment. Moreover, the current information is actively maintained only until new stimuli arise, and this new perceptual processing is not affected by the previous one.

Table 4: statistical analyses of between groups effects

Hemisphere	Between group
Left	rest 1, F(1, 1472) = 11.403, p<0.001
	meditation F(1,1444) = 73.257, p < 0.001
	rest 2 F(1,1472)= 94.981, p<0.001
Right	rest 1 F(1,1485)= 28.600, p<0.001
	meditation F(1,1459)= 94.688, p<0.001
	rest 2 F(1,491)= 72.526, p<0.001

Therefore, an enhanced concentration during meditation might correlate with an increase in theta oscillations, independently of the level of expertise, if some level of concentration is reached. Perhaps the most interesting finding of the present study was that, although an acute increase in theta activity during meditation was seen in both groups, the meditators showed a lower trait FT. Because meditation improves attention and concentration, constant training in

OM limits the overuse of working memory18, and, therefore, it may be associated with the lower levels of FT observed in the MG compared to the NMG. We suggested that this finding was a neural correlate of the expert practitioners' ability to limit the processing of unnecessary information (e.g., discursive thought) and increase awareness of the essential content of the present experience with an attitude of acceptance. According to Chiesa et al.19, this is a clear description of a bottom-up regulatory process.

Furthermore, attention is also thought to act as a gate to working memory20. Thus, theta band increases in the frontal area have been associated with the active maintenance of working memory representations8,21–23 and this relevant information in an active state has influence on future perceptual processing, thought, and behavior20. Thereby, in this study, the NMG was unaware of OM (new processing) despite the clear instructions that had been given just before the task. This processing generated an increase in mental activity, and a high perceptual process load can impair the ability to detect stimuli in environments that overload the working memory24. It might worsen attention and concentration, resulting in a decrease in vigilance and an increase in mental effort when associated with another low frequency, such as alpha25, and this may partly explain our findings.

Another important finding was that we did not find a significant difference between the rest conditions and meditation at the prefrontal derivations (Fp1, Fp2) in the MG. The finding that the activation level in the prefrontal area remained constant for the meditators, whether they were meditating or not, was an indicator that the ability of these subjects to control their narrative focus was not exclusive of formal meditation. The typical narrative focus (e.g., discursive thought) impairs attentional performance and involves mental elaboration and evocation, which overload the working memory processing. The prefrontal cortex (PFC) is responsible for the coordination of all of this mental traffic in working memory, and mindfulness training possibly enhances the ability of the PFC to maintain high attention levels outside of formal meditation26. This is clearly a top-down process, which involves the executive control of attention and the modulation of emotional limbic structures19. Therefore, it is clear that, although bottom-up processes explain in part the role of mindfulness as an emotion regulation strategy19, there are also top-down processes that are important in regulating attention.

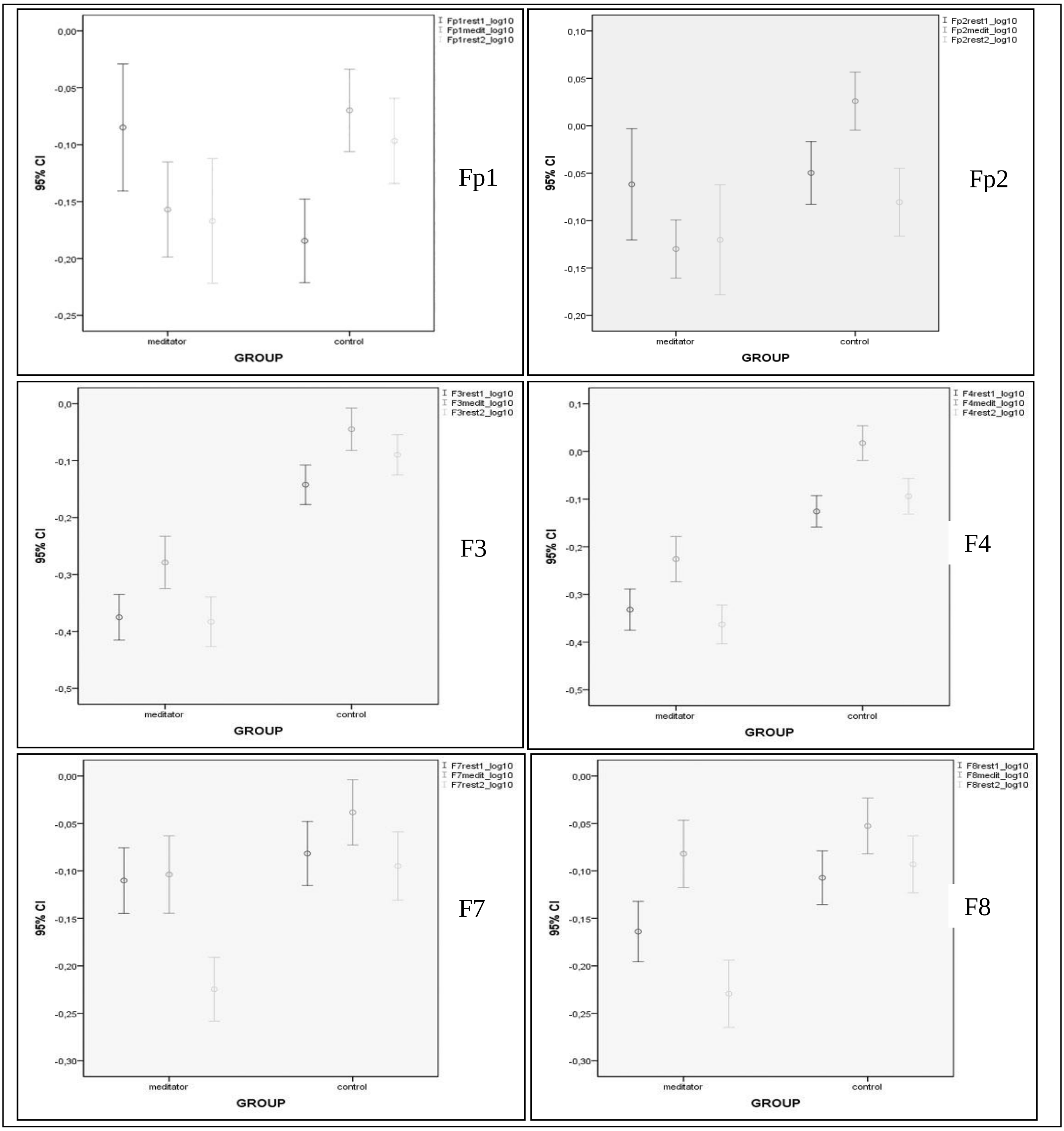

Figure 1: Profile plots of significant absolute theta power at frontal areas (μV²/Hz).

Table 5: Absolute theta power (μV²/Hz) means for both groups in the three conditions

μV²/Hz	Right frontal			Left frontal		
	Rest 1	Medit	Rest 2	Rest 1	Medit	Rest 2
Meditator	-0.185	-0.148	-0.236	-0.185	-0.184	-0.247
Control	-0.97	-0.004	-0.094	-0.129	-0.043	-0.086

Table 6: statistical analyses of within groups effects

Electrodes	Within meditator group		Within control group	
Left	p<0.001	rest1 and meditation (p=0.873)	p<0.001	rest1 and meditation (p<0.001)
		meditation and rest2 (p<0.001)		meditation and rest2 (p<0.001)
		rest1 and rest2 (p<0.001)		rest1 and rest2 (p<0.001)
Right	P<0.001	rest1 and meditation (p=0.014)	p<0.001	rest1 and meditation (p<0.001)
		meditation and rest2 (p<0.001)		meditation and rest2 (p<0.001)
		rest1 and rest2 (p<0.001)		rest1 and rest2 (p=1.00)

Chiesa et al.19 have suggested that mindfulness training is associated with bottom-up emotional regulation in long-term practitioners and with top-down emotional regulation in short-term practitioners according to different conceptions of mindfulness as an emotional regulation strategy. However, we suggest that top-down processing is also present in experienced practitioners, although it is reduced as bottom-up processing becomes emphasized. The top-down processing facilitates positive reappraisal, thus recruiting PFC regions that are associated with emotional reappraisal19,27,28. This is in accordance with our findings because the NMG significantly increased their left prefrontal activity during meditation (with only brief meditation instructions), which was probably related to the better executive control of attention, including positive reappraisal, as this area of the cortex has been linked to positive affect29,30. Indeed, these subjects maintained greater activity at the left PFC (Fp1) during rest 2, which can be associated with an increased mood that persists after meditation.

When we averaged the frontal sensors into a single measure of the left and right hemispheres, we found similar results in comparison to the individual prefrontal electrodes for the NMG. For the MG, we also did not find a significant difference between rest 1 and meditation in the left hemisphere for Fp1 (left prefrontal). These results possibly indicated an important role of the PFC in coordinating attention and emotion regulation processes in the MG. This top-down processing was more emphasized in the NMG, although it was still important for the long-term meditators (MG). We suggest, based on the evidence of the emotion asymmetry in the PFC30, that the top-down regulation of positive reappraisal was related to left PFC activity, which was increased in meditators at rest and increased during meditation for the NMG. Our findings were consistent with the mindfulness-related present-moment focus, which is thought to improve well-being by allowing individuals to refrain from trying to control the content of the mind and to become aware of sensations, emotions, and thoughts without judgment or reactivity31.

In summary, many differences were found in this study. As we expected, long-term meditation practice altered the oscillatory pattern of the theta band, which has been associated with cognitive functions, such as executive attention and working memory. Despite the acute increase in theta activity during meditation in both groups, the meditators showed a lower trait FT. This was consistent with a reduced top-down control of attention and increased present moment awareness. In conclusion, acute changes in the theta band throughout meditation did not seem to be a specific correlate of OM, but it was rather related to the concentration properties of meditation. Notwithstanding, lower FT activity appeared to be a trait of OM practice. The present study did not analyze the ratio of gamma-band activity (25–42 Hz) to slow oscillatory activity (4–13 Hz), which could be enlightening. Further research is encouraged to evaluate the electrophysiological correlates of OM meditation.

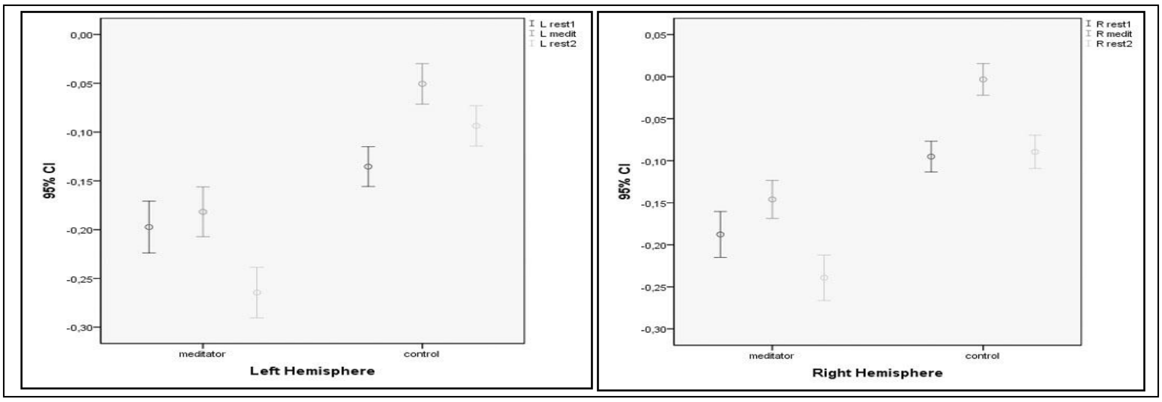

Figure 2 - Profile plots of error bar theta power at frontal areas (μV²/Hz).

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4.2 ARTIGO II: **Effortless Attention as a Biomarker for Experienced Mindfulness Practitioners**

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Effortless attention as a biomarker for experienced mindfulness practitioners

Guaraci Ken Tanaka[2,3,9], Tolou Maslahati[10], Mariana Gongora[1], Juliana Bittencourt[2,9,13], Luiz Carlos Serramo Lopez[12], Marcelo Marcos Piva Demarzo[3], Henning Budde[10,11], Silmar Teixeira[4], Luis Fernando Basile[5,14], Javier Garcia Campayo[6], Mauricio Cagy[8], Pedro Ribeiro[1,2,7], Bruna Velasques[2,7,9]

1. Brain Mapping and Sensory Motor Integration, Institute of Psychiatry of the Federal University of Rio de Janeiro (IPUB/UFRJ), Rio de Janeiro, Brasil;
2. Institute of Applied Neuroscience (INA), Rio de Janeiro,Brasil;
3. Mente Aberta, Brazilian Center for Mindfulness and Health Promotion, Federal University of Sao Paulo (UNIFESP), São Paulo, Brasil;
4. Brain Mapping and Plasticity Laboratory, Federal University of Piauí (UFPI),Piaui, Brasil;
5. Laboratory of Psychophysiology, Faculdade da Saúde, UMESP, São Paulo, Brazil
6. Migue Servet University Hospital. Aragonese Institute of Health Sciences. University of Zaragoza, Zaragoza, Spain
7. Bioscience Department, School of Physical Education of the Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brasil;
8. Biomedical Engineering Program, COPPE, Federal University of Rio de Janeiro, Rio de Janeiro, Brasil;
9. Neurophysiology and Neuropsychology of Attention, Institute of Psychiatry of the Federal University of Rio de Janeiro (IPUB/UFRJ), Rio de Janeiro, Brasil;
10. Faculty of Human Sciences, Medical School Hamburg, Hamburg, Germany;
11. Sport Science, Reykjavik University, Reykjavik, Iceland;
12. Behavioral Ecology and Psychobiology Laboratory, Department of Systematics and Ecology, Universidade Federal da Paraiba (UFPB), Paraíba, Brasil;
13. Veiga de Almeida University, Rio de Janeiro, Brasil.
14. Division of Neurosurgery, Department of Neurology, University of São Paulo Medical School, São Paulo, Brasil

Abstract

Objective: The present study aimed at comparing frontal beta power between long-term (LTM) and first-time meditators (FTM), before, during and after a meditation session. We hypothesized that LTM would present lower beta power than FTM due to lower effort of attention and awareness.

Methods: Twenty one participants were recruited, eleven of whom were long-term meditators. The subjects were asked to rest for 4 minutes before and after open monitoring (OM) meditation (40 minutes).

Results: The two-way ANOVA revealed an interaction between the group and moment factors for the Fp1 ($p<0.01$), F7 ($p=0.01$), F3 ($p<0.01$), Fz ($p<0.01$), F4 ($p<0.01$), F8 ($p<0.01$) electrodes.

Conclusion: We found low power frontal beta activity for LTM during the task and this may be associated with the fact that OM is related to bottom-up pathways that are not present in FTM.

Significance: We hypothesized that the frontal beta power pattern may be a biomarker for LTM. It may also be related to improving an attentive state and to the efficiency of cognitive functions, as well as to the long-term experience with meditation (i.e., life-time experience and frequency of practice).

Introduction

Many studies seek to understand the neurophysiology of sustained attention (CHIESA; SERRETTI, 2010; FIEBELKORN et al., 2012; KLIMESCH, 2012; LUTZ et al., 2009; MITCHELL et al., 2008). In conditions when more external stimuli than can be fully processed activate the central nervous system

(CNS), attentional impairments result , such as stress, distraction, forgetfulness, anxiety, memory loss, and fatigue (BORGHINI et al., 2012; LAVRETSKY, 2009; VAGO; SILBERSWEIG, 2012). This impairment is discussed in studies of working memory, default mode network, and attentional disorder studies. Recent studies have demonstrated the role of meditation as an important tool for attention management (DICKENSON et al., 2012; KABAT-ZINN et al., 1992; YU et al., 2011).

In this context, mindfulness meditation is one important method that increases attention performance. Specially, some studies demonstrated that a specific type of mindfulness, Open Monitoring (OM) (LUTZ et al., 2008), increases posterior alpha power with a high frontal theta power (CHIESA, 2009; LAGOPOULOS et al., 2009). Researchers also observed that experienced OM meditators showed an increase of occipital and frontoparietal gamma activity, due to an improvement of sensory awareness (CAHN; DELORME; POLICH, 2010). Beta activity in relation to meditation has only been investigated in a few studies until now. In the current literature we have found four studies that examined beta power and meditation. One study observed the general increase of beta power in the elderly meditation novices (AHANI; WAHBEH, 2013). Dor-Ziderman et al. (2013) investigated the long-term OM and observed a beta power decrease in the ventral medial prefrontal cortex (DOR-ZIDERMAN et al., 2013). Further studies showed a different pattern of frontal beta power when compared to another meditation practice (HAUSWALD et al., 2015; HINTERBERGER et al., 2014).

OM meditation favors sustained attention without judgment of ongoing phenomena (LUTZ et al., 2008). These mindfulness properties are thought to improve self-regulation and stress management by allowing individuals to refrain from trying to control the content of mind (COLZATO; OZTURK; HOMMEL, 2012; KUBOTA et al., 2001; PERLMAN et al., 2010). Nevertheless, we suggest that frequency plays an important role when comparing long-term meditators (LTM) with first-time meditators (FTM), particularly regarding activity in the frontal areas (HAUSWALD et al., 2015; KUBOTA et al., 2001; MORAES et al., 2007). Beta band frequency (13-30Hz) is associated with attention, vigilance and processing information (HUANG; LO, 2009; SEGAL; WILLIAMS; TEASDALE, 2002), but the literature regarding the neurophysiology of frontal beta activity and meditation is scant. We observed a lack of consistent reports on the regulatory mechanisms of beta oscillations related to the self-awareness process in OM. In this context, the aim of the present study was to investigate frontal beta power differences between long-term and first-time meditators, before, during and after a meditation session. We expected increased beta for both groups during OM versus during rest, before and after OM, but generally lower beta in LTM vs. FTM due to lower sustained attention effort expected in the group of experienced meditators..

Materials and Methods

Participants

We recruited twenty-one participants, out of which eleven were experienced meditators (7 men, mean age 43,8 ± 17,53) and ten were healthy first-time meditators (5 men, mean age 40,10 ± 14,72). The group of experienced meditators includes monks and laymen from various Buddhist traditions, and were recruited from three major meditation centers (i.e., Zen, Kadampa and Vipassana), localized around the Federal University of Rio de Janeiro (UFRJ). The group of first-time meditators (i.e., control group) was recruited at the UFRJ. We contacted all the participants two weeks before starting the research. The condition for the experienced meditators was to have been practicing regularly at least for the last five years (12,23 years of practice ± 7,65), while living under the same social conditions as the control group (i.e. in the same city, and to be exposed to the same environment; i.e., no secluded life in Buddhist centers). All participants were medication-free and had no sensory, motor, cognitive or attention deficits that could affect their performance. Subjects gave their written consent (according to the Helsinki Declaration) to participate in the study. The Ethics Committee of the Federal University of Rio de Janeiro (IPUB/UFRJ) approved the experiment.

Task protocol

Subjects sat in a straight position, in a darkened and noise-free room, to minimize sensory interference. First, we recorded 4 minutes of resting EEG (resting instructions were particularly emphasized for meditators, to refrain them from entering the meditative state). After that the subjects were recorded while performing the OM for 40 minutes. The experiment ended by recording 4 minutes of rest again. An auditory signal marked the beginning and end of each stage.

Mindfulness instructions for LTM and FTM were: “pay attention to whatever comes into your awareness. Whatever it is, a stressful thought, an emotion or body sensation, just let it pass in an effortless way, without trying to maintain it or change it in any way, until something else comes into your consciousness”(BREWER et al., 2011). The researcher gave the instructions right before the start of the practice, as we believed this would promote better motivation as a first attempt of a new activity. Due to its simplicity, the technique could be implemented by all subjects, and we considered this as particularly important, since subjects reported that they had no problems to follow the instructions.

EEG recording

The International 10/20 EEG electrode system (Jasper, 1958) was used with a 20-channel EEG system (Braintech-3000, EMSA Medical Instruments, Brazil). The 20 electrodes were arranged on a nylon cap (ElectroCap Inc., Fairfax, VA, USA) yielding mono-polar derivation using the earlobes as reference. The impedance of EEG and EOG electrodes was kept between 5-10 kΩ. The amplitude of the recorded data was less than 70μV. The EEG signal was amplified with a gain of 22.000 Hz, analogically filtered between 0.01Hz (high-pass) and 80Hz (low-pass), and sampled at 200 Hz. The software *Data Acquisition* (Delphi 5.0) from the Brain Mapping and Sensory Motor Integration Lab, was employed with the notch (60 Hz) digital filter.

Data analysis

Data analysis was performed by using MATLAB 5.3 (Mathworks, Inc.) and EEGLAB toolbox (http://sccn.ucsd.edu/eeglab). We applied a visual inspection and Independent Component Analysis (ICA) to remove possible sources of artifacts produced by the task (i.e., blink, muscle). We collected the data using the bi-auricular reference. Furthermore the data was transformed (re-referenced) to common average reference, after conducting the artifact elimination by ICA filtering.

At first, we divided the tasks (rest 1, meditation, rest 2) into segments of 6000 data points, corresponding to 30-second blocks. Secondly, as meditation trials lasted 40 minutes (KABAT-ZINN, 1990; SEGAL; WILLIAMS; TEASDALE, 2002; SOLER et al., 2014), we chose to analyze eight blocks (total of 4 min), corresponding to the moment between 30-34 minutes, which is consistent with the moment in which experienced meditators recognize entering a deeper state (HUANG; LO, 2009). For that moment we had 24 trials of 30-second blocks. A fast Fourier transform method was used to obtain the mean power amplitudes in the beta (13-30 Hz) band.

The number of samples was 6000 (30s × 200Hz) with rectangular windowing. We calculated absolute beta power on each lead individually every four seconds, totaling seven excerpts for each block. Thus, 1680 was the total data of the control group (24 trials x 7 absolute power samples x 10 subjects) and 1848 the total data of the meditator group (24 trials x 7 absolute power samples x 11 subjects). In fact, this sampling rate is commonly used in other frequencies, but we focused on the beta band due to a specific analyzis (BITTENCOURT et al., 2012; CARTIER et al., 2012). As the data was not normally distributed, a logarithmic transformation was used.

Statistical analysis

In the statistical analysis, we log10-transformed the EEG absolute power values by the SPSS software (version 15.0) to approximate a normal distribution. We performed a two-way ANOVA and a post hoc test (Bonferroni) to analyze the factor group (LTM x FTM) and moment (rest 1, meditation and rest 2) of absolute beta power for each electrode individually. The effect size was calculated as Cohen's d, i.e., changes' mean divided by changes' SD.

We also performed a t-test for all frontal electrodes (Fp1, Fp2, F3, Fz, F4, F7 and F8) comparing LTM versus FTM groups for each moment (rest 1, meditation and rest 2).

Results

We analyzed absolute beta power in the frontal area (i.e., Fp1, Fp2, F3, Fz, F4, F7 and F8 electrodes). The two-way ANOVA revealed an interaction between the group and moment factors for the Fp1 ($p<0.01$), F7 ($p=0.01$), F3 ($p<0.01$), Fz ($p<0.01$), F4 ($p<0.01$), F8 ($p<0.01$) electrodes. Examining the Fp1 interaction, we identified a difference between rest 1 and rest 2; and between meditation and rest 2 for LTM. Specifically, we found a higher beta power for rest 2 when compared to the other moments. We did not find a difference between rest 1 and meditation for LTM. For the FTM group, we observed a difference between rest 1 and meditation; and between rest 1 and rest 2. This group presented lower beta power for rest 1 when compared to the other moments. In other words, beta is increased from rest 1 during meditation for FTM and there is no difference from rest 1 to meditation for LTM (fig1 and table 1). For this electrode, a t-test between groups showed significant difference only for rest 1 and meditation (table 2). For F3 and Fz, both FTM and LTM had lower beta power at rest 1, when compared to meditation and rest 2 (fig 1 and table 1). For these electrodes, a t-test between groups showed significant difference for rest 1, meditation and rest 2 (table 2). For F4, the LTM and FTM had lower beta power at rest 1 when compared to meditation and rest 2 (fig 1 and table 1). As opposed to that, FTM beta power was lower at rest 2, when compared to meditation and higher than rest 1 (fig 1 and table 1). For this electrode, a t-test between groups showed significant difference only for meditation and rest 2 (table 2). For F7, both LTM and FTM had lower beta power at rest 1, when compared to meditation and rest 2 (fig 1 and table 1). For this electrode, a t-test between groups showed significant difference for rest 1, meditation and rest 2 (table 2). Examining the interaction for F8, we found a difference between meditation and rest1, and meditation and rest 2 for LTM. We also identified difference among all the moments for FTM (table 1). For this electrode, a t-test between groups showed significant difference for rest 1, meditation and rest 2 (table 2).

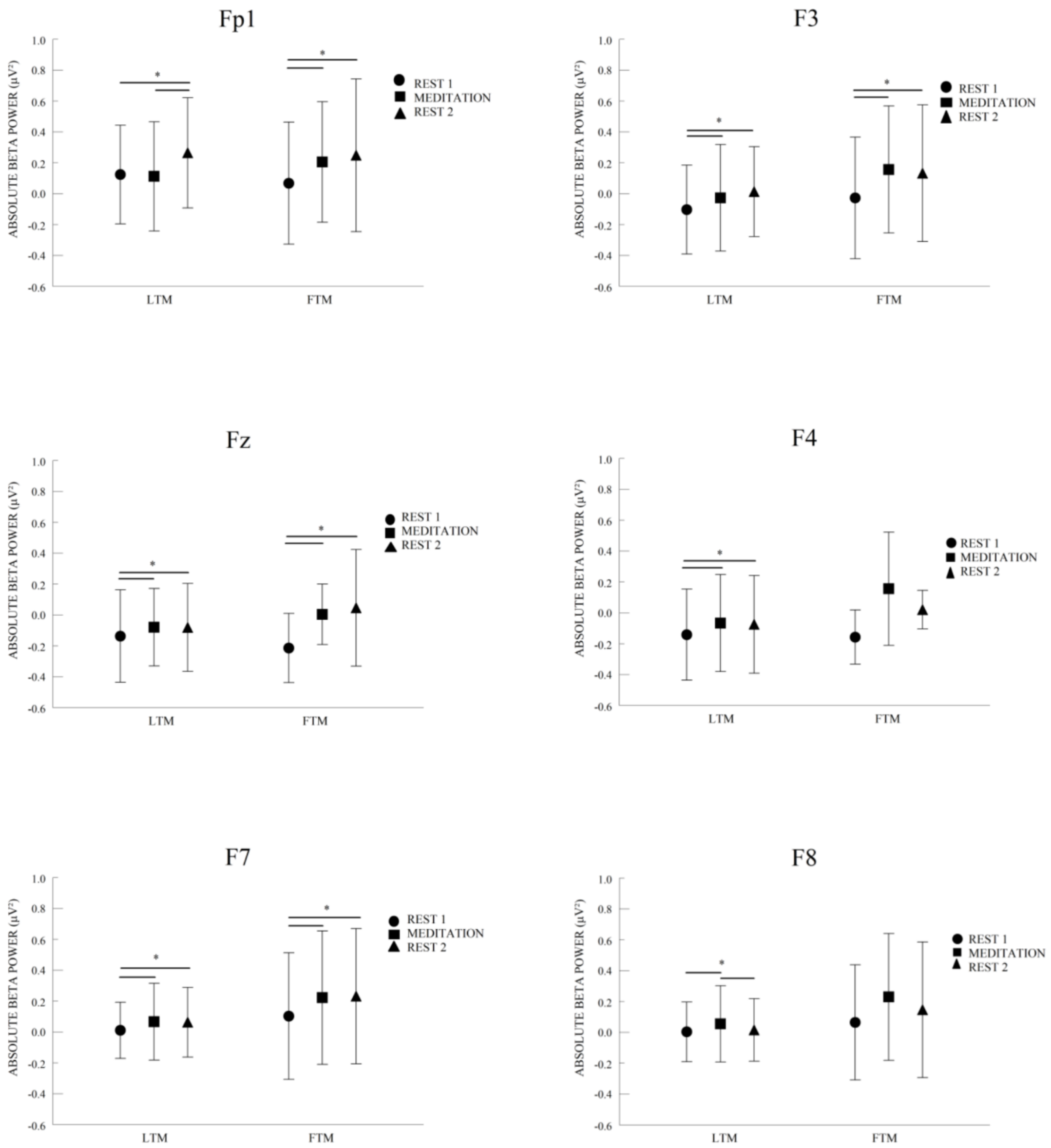

Fig 1 - Comparisons of LONG-TERM (LTM) and FIRST-TIME (FTM) meditators in the moment (rest 1 (●); meditation (■); rest 2 (▲)) for all frontal electrodes. Data represent the mean ± SD frequency of logged absolute beta power (log10 transformed) for each electrode. A 2 × 3 ANOVA showed significantly differences in the marked bars ($p < 0.05$; exact values in table 1). (* represents significant p values) The bars represent the moments that demonstrate difference between them when we examining the interaction.

We found a main effect for group and moment for the Fp2 electrode. A main effect for group with a lower absolute beta power was found for the LTM, when compared to the FTM. A main effect for moment with a lower absolute beta power was found at rest 1, rather than for meditation and rest 2; also beta was lower at meditation than at rest 2 (fig 2). To further explore the Fp2 result, we applied a one-way ANOVA for each group separately. We did not find differences between rest1-meditation, only for LTM (fig 1 and table 1). We found significant differences between groups for all frontal electrodes together (Fp1, Fp2, F3, Fz, F4, F7 and F8) using a t-test for each moment ($p<0.01$) (fig 3).

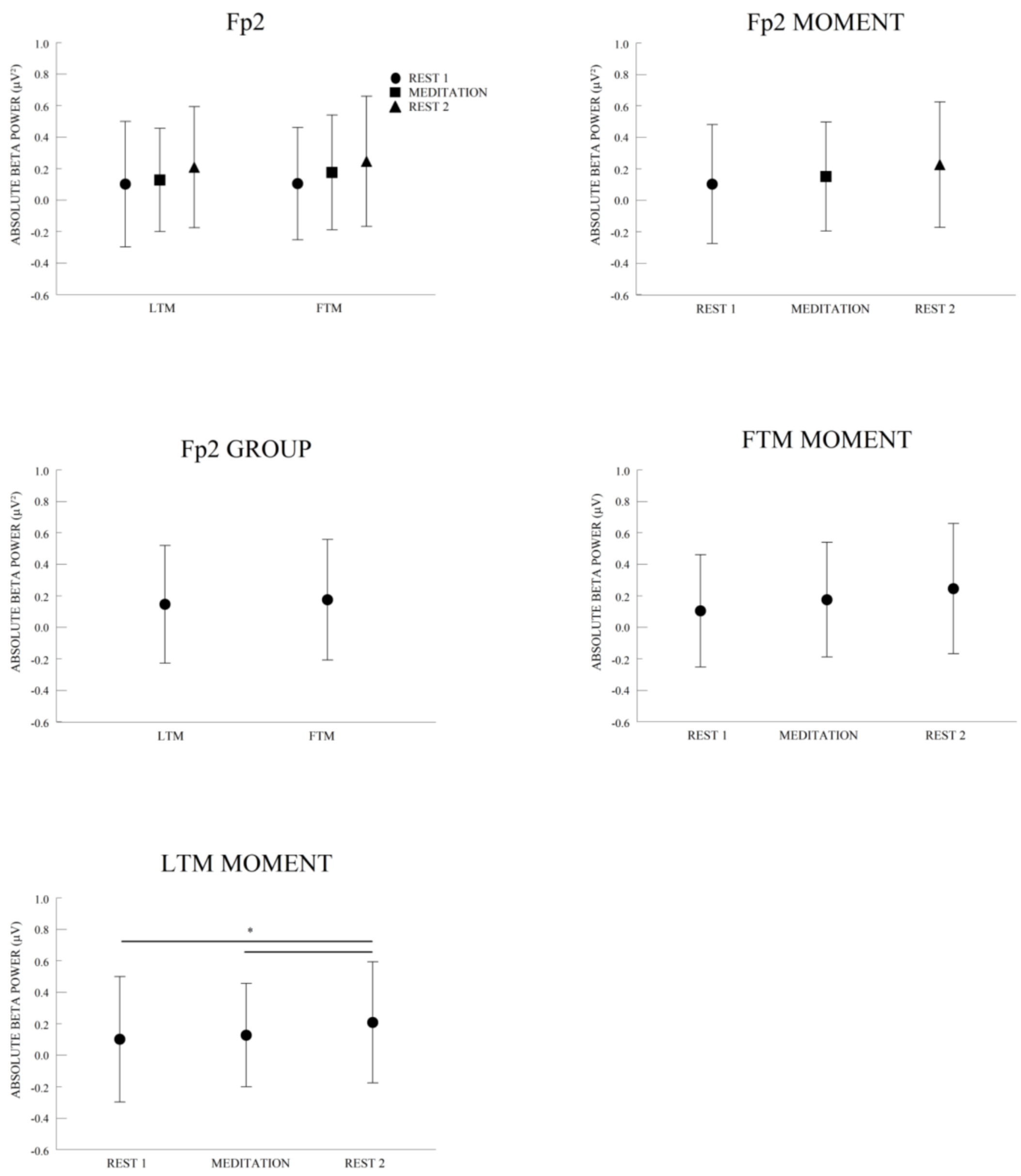

Fig 2 - A 2 × 3 ANOVA design showed a main effect for group and moment for Fp2 electrode. a) Comparisons of LTM and FTM absolute beta power (logged mean ± SD) (log10 transformed) showed significant differences between groups ($p=0.02$); b) Comparisons of rest 1, meditation and rest 2 absolute beta power (logged mean ± SD) (log10 transformed) showed a significant increase for rest 1 to meditation ($p=0.01$), meditation to rest 2 ($p<0.01$) and rest 1 to rest 2 ($p<0.01$).

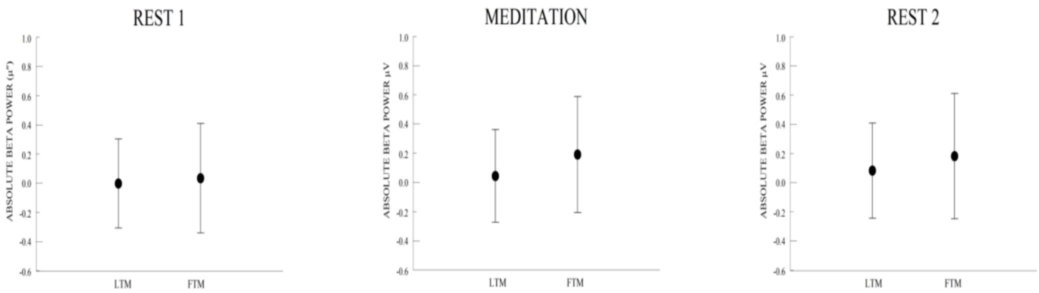

Fig 3 - A t-test showed a significant difference for frontal beta activity in the rest 1 ($p<0.01$), meditation ($p<0.01$) and rest 2 ($p<0.01$) when compared LTM to FTM. All frontal electrodes are included (Fp1, Fp2, F3, Fz, F4, F7 and F8) and separated for each moment.

Table 1 - Group x Moment t-test of within groups effects showing p-values and effect size (Cohen’s d) representing differences between two groups. (* represents significant p values).

ELECTRODES (ETA)	GROUP	REST1-MEDIT (Cohen´s)	MEDIT-REST2 (Cohen´s)	REST1-REST2 (Cohen´s)
Fp1 (0.007)	LTM	0.33 (-0.05)	<0.01* (-0.25)	<0.01* (-0.22)
	FTM	<0.01* (-0.39)	0.09 (-0.10)	<0.01* (-0.44)
Fp2 (0.331)	LTM	0.22 (-0.07)	<0.01* (-0.22)	<0.01* (-0.27)
	FTM	<0.01* (-0.19)	<0.01* (-0.18)	<0.01* (-0.36)
F3 (0.004)	LTM	<0.01* (-0.34)	0.02* (0.18)	<0.01* (-0.40)
	FTM	<0.01* (-0.40)	0.33 (0.03)	<0.01* (-0.35)
F4 (0.028)	LTM	<0.01* (-0.29)	0.33 (0.18)	<0.01* (-0.21)
	FTM	<0.01* (-0.45)	<0.02* (0.18)	<0.01* (-0.25)
Fz (0.023)	LTM	<0.01* (-0.25)	0.33 (0.18)	<0.01* (-0.20)
	FTM	<0.01* (-0.40)	0.01* (0.10)	<0.01* (-0.40)
F7 (0.002)	LTM	<0.01* (-0.31)	0.33 (0.06)	<0.01* (-0.15)
	FTM	<0.01* (-0.31)	0.33 (-0.03)	<0.01* (-0.35)
F8 (0.005)	LTM	<0.01* (-0.29)	<0.01* (0.20)	0.33 (-0.11)
	FTM	<0.01* (-0.34)	<0.01* (0.16)	<0.01* (-0.16)

Table 2 – Group x Moment Interaction. T-Test of between groups for each moment, showing p-values and effect size representing differences between two groups. (* represents significant p values).

ELECTRODES	REST 1	MEDITATION	REST 2
Fp1	<0.01* (0.14)	<0.01* (-0.23)	0.52 (-0.20)
Fp2	0.88 (-0.01)	0.02* (-0.14)	0.11 (-0.09)
F3	<0.01* (-0.32)	<0.01* (-0.43)	<0.01* (-0.40)
Fz	<0.01* (0.28)	<0.01* (-0.41)	<0.01* (-0.55)
F4	0.33 (0.32)	<0.01* (-0.53)	<0.01* (-0.48)
F7	<0.01* (-0.34)	<0.01* (-0.40)	<0.01* (-0.56)
F8	<0.01* (-0.34)	<0.01* (-0.50)	<0.01* (-0.43)

Discussion

The aim of this study was to clarify the neurophysiology of absolute beta power in the frontal area comparing FTM and LTM performing OM meditation. We hypothesized that attentional regulation promotes an altered frontal beta modulation(BENCHENANE; TIESINGA; BATTAGLIA, 2011; CHIESA; SERRETTI; JAKOBSEN, 2013; VAN DEN HURK et al., 2010). We observed that the maintenance of attention in the present moment produced lower frontal beta power in LTM when compared to FTM (Figure 3), representing a specific meditative trait. Our preliminary results indicate a beta power increase in the frontal area during meditation for both groups. The findings are supported by the previous studies relating beta activity and attentional state (BOB et al., 2013; ENGEL; FRIES, 2010; MORAES et al., 2007; ROCA-STAPPUNG et al., 2012; TRAVIS; SHEAR, 2010). Therefore, some studies have shown different understanding about OM mechanisms, as discussed below.

Frontal beta rhythm is prevalent during attentional activity. However, its role in the meditative state remains unclear. Beta is a low-mid frequency range rhythm that is detected when subjects are alert and in an attentive state (CHIESA; SERRETTI, 2010; TRAVIS; SHEAR, 2010), and also reflects the oscillation of the anticipatory processes in the motor system (ENGEL; FRIES, 2010; GOLA et al., 2012). Moreover, this process seems to be different in OM.

Previous studies demonstrated that OM improves self-regulation and stress management by allowing individuals effortless attention processing (BERKOVICH-OHANA et al., 2013; CAVANAGH et al., 2013; CRESWELL et al., 2012).

The literature has shown that the intensity and life-time experience of meditation practice contribute to the progression of the mental training (CHIESA; SERRETTI; JAKOBSEN, 2013; KERR et al., 2013; VAGO, 2014). Moreover, previous studies have shown that OM practice improves the maintenance of attention depending on the time of training and may contribute to the efficiency of the cognitive processes such as executive processing (i.e. working memory)(BENCHENANE; TIESINGA; BATTAGLIA, 2011). Likewise, LTM are able to modulate emotion and cognition through the bottom-up pathways without the main influence of the prefrontal cortex(VAN DEN HURK et al., 2010).

The opposite pattern is noted with FTM, showing a high cognitive control to modulate attention and perception, suggesting a top-down regulation(CHIESA; SERRETTI; JAKOBSEN, 2013; VAN DEN HURK et al., 2010). In this case, it is expected that the FTM present higher beta power. Our results are in agreement with this hypothesis. We found a similar beta pattern for both groups at all the moments investigated (rest 1, meditation, rest 2). However, we observed that FTM presented a higher beta band during meditation when compared to LTM for all electrodes observed, except for the right prefrontal cortex (i.e., Fp2), as showed in Fig.1. In other words, we suggest that FTM`s higher beta in the frontal cortex occurs due to the fact that this group exerts more effort to maintain the attention fixed on a specific thought or sensation, also called “object” (i.e. breath, body sensation); this is seen in FTM more than in LTM, who are already better trained to sustain the OM practice(HINTERBERGER et al., 2014).

The OM practice provides a dynamic flow of attention different from focused attention(SEDLMEIER et al., 2012). Some mindfulness body scan studies have shown a misperception decrease and a sensitivity increase(FOX et al., 2012; MIRAMS et al., 2013; SAGGAR et al., 2012) in case of distress deriving from unpleasant body sensations, such as pain sensitization(JHA et al., 2010; USSHER et al., 2014). Recently, Engel and Fries (2010)(ENGEL; FRIES, 2010) demonstrated that top-down and bottom-up frontal beta activities are associated with expectancy of the following event, thus also manifesting attentional activity(SLAGTER; DAVIDSON; LUTZ, 2011).

Although we did not measure the level of expectancy of our subjects, we hypothesized that the beta power increased in FTM was also associated with the level of expectancy and low flexibility of sustained attention without focus on a specific object. In this context, the differences between the groups are associated with the meditator´s ability to modulate sensation and perception strategies (CHIESA; SERRETTI; JAKOBSEN, 2013). The OM meditative state depends on a specific mental training which is optimized by the experience and/or time of practice, and it is only generated arousal and motivation (SLAGTER; DAVIDSON; LUTZ, 2011).

Other recent studies have implicated different pathways to explain lower frontal activity during the attentional process, observing that the prefrontal cortex does not modulate attention processing during the OM practice. The discussion is based on the bottom-up processing during OM meditative state.

This meditative practice, often viewed as an emotional regulation strategy, has been associated with a lower frontal cortex activity (CHIESA; SERRETTI; JAKOBSEN, 2013; GRANT; COURTEMANCHE; RAINVILLE, 2011). At the same time hyperactivity occurs in the prefrontal cortex when related to an altered state working memory, executive attention, emotional reappraisal and cognitive monitoring(BROWN; JONES, 2010; CHIESA; SERRETTI; JAKOBSEN, 2013; VAN DEN HURK et al., 2010).

Furthermore, this increased activity is also associated with the narrative focus, occurring mainly in the medial prefrontal cortex. The typical narrative focus (e.g. discursive thought) impairs attention-task performance, involving mental elaboration and evocation and overloading working memory processes (TANAKA et al., 2014). Examining the interaction in Fp1, we observed that for FTM the rest 1 is different from the meditation moment; and we did not find this difference for the LTM (Figure 1 and table 1). Our results also demonstrated that lower beta power found for LTM is related to effortless attention, which is not found for FTM. This finding suggest that experienced meditators are trained to maintain the attention state even before starting the meditation; which suggests that the meditation training regularity improves attention. The LTM medial prefrontal cortex (Fz) showed higher beta power at rest 1, due to the maintenance of the self-referential mental processing even when not meditating(SLAGTER; DAVIDSON; LUTZ, 2011). This pattern was different during meditation on account of a lower activity of the LTM supporting the effortless hypothesis. In both situations, increased beta power was observed during meditation, but the FTM showed higher power than LTM.

In conclusion, LTM have a particular trait, which differentiates them when compared to FTM. Lower frontal beta activity is associated with the particularity of OM being related to bottom-up pathways. On the other hand, an increased activity in the frontal area has been found when attention was focused on a specific object, used as an attentive state maintenance tool by FTM more than by LTM. We hypothesize that this pattern associated with LTM improved their attentive state, while maintaining low cognitive demands. Due to the enhanced learning, related both to time and intensity of practice, it may be a promising biomarker to differentiate experienced mindfulness practitioners in further studies.

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4.3 ARTIGO III: **Mindfulness as a non cognitive process for experienced meditators: a fronto-parietal gamma coherence analysis**

Mindfulness 2016
(In review)

Mindfulness as a non cognitive process for experienced meditators: a fronto-parietal gamma coherence analysis

Guaraci Ken Tanaka[b,c,i*], Juliana Bittencourt[b,i,m], Mariana Gongora[a], Luiz Carlos Serramo Lopez[cl], Marcelo Marcos Piva Demarzo[c], Henning Budde[j,k], Silmar Teixeira[d], Luis Fernando Basile[e], Carlos Escolano[n], Javier Garcia Campayo[f], Elisa Harumi Kozasa[j], Mauricio Cagy[h], Pedro Ribeiro[a,b,g], Katie Witkiewitz[o] Bruna Velasques[b,g,i]

a. Brain Mapping and Sensory Motor Integration, Institute of Psychiatry of the Federal University of Rio de Janeiro (IPUB/UFRJ), Rio de Janeiro, Brasil;
b. Institute of Applied Neuroscience (INA), Rio de Janeiro,Brasil;
c. Mente Aberta, Brazilian Center for Mindfulness and Health Promotion, Federal University of Sao Paulo (UNIFESP), São Paulo, Brasil;
d. Brain Mapping and Plasticity Laboratory, Federal University of Piauí (UFPI),Piaui, Brasil;
e. Laboratory of Psychophysiology, Faculdade da Saúde, UMESP, São Paulo, Brazil
f. Migue Servet University Hospital. Aragonese Institute of Health Sciences. University of Zaragoza, Spain
g. Bioscience Department, School of Physical Education of the Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brasil;
h. Biomedical Engineering Program, COPPE, Federal University of Rio de Janeiro, Rio de Janeiro, Brasil;
i. Neurophysiology and Neuropsychology of Attention, Institute of Psychiatry of the Federal University of Rio de Janeiro (IPUB/UFRJ), Rio de Janeiro, Brasil;
j. Hospital Israelita Albert Einstein, São Paulo, Brazil;
k. Sport Science, Reykjavik University, Reykjavik, Iceland;
l. Behavioral Ecology and Psychobiology Laboratory, Department of Systematics and Ecology, Federal University of Paraiba (UFPB), Paraíba, Brasil;
m. Veiga de Almeida University, Rio de Janeiro, Brasil.
n. Bit & Brain Technologies SL, Zaragoza, Spain
o. Department of Psychology, University of New Mexico, Albuquerque, NM, USA

*address: Av. Venceslau Braz 71, zipcode: 22290-140; mail: fisioken@gmail.com

ABSTRACT

The fronto-parietal network is associated with working memory, visual perception awareness, self-narrative and sensory motor integration. EEG coherence is a coupling measure between areas showing the relative strength between two electrodes. This study investigated the differences in intra-hemispheric frontoparietal gamma coherence (FPGC) between experienced meditators (EM) and non-meditators (NM) before, during and after open monitoring meditation. We hypothesized that mindfulness expertise is associated with higher frontoparietal gamma coherence as a characteristics of the open monitoring training. As a main result, we found lower gamma coherence for EM during meditation when compared to pre and post rest, while gamma coherence for NM was greater during meditation when compared to the other moments. Nevertheless, the frontoparietal gamma coherence was higher for EM in all moments (rest 1, meditation and rest 2) of the electrodes pairs analyzed when compared to NM. In summary, the long lasting training (i.e. EM) is able to improve gamma coherence of the fronto-parietal area only at rest.

Keywords: fronto-parietal network, gamma coherence, open monitoring, mindfulness

1. Introduction

The number of publications examining the relationship between attentional processing and mindfulness meditation has increased in recent years, with a considerable focus on the neurobiological correlates of mindfulness (often accessed via electroencephalography (EEG) or magnetic resonance imaging (MRI)). Preview studies have shown differences between experienced meditators and novice which presented lower frequency as specific trait or state to experienced meditators (Lomas et al. 2015). The increase of the alpha and theta band was related to relaxation during meditative attentive task and this pattern was correlated to anterior cingulate cortex and prefrontal cortex (Cahn & Polich 2006; Chiesa & Serretti 2010). For example, Baijal and Srinivasan found an increase of theta activity in the frontal area associated with increased concentrative focus on an object. An interesting point of this study was a reduction in activity in the parieto-occipital area, possibly reflecting a reduction in self-awareness (Baijal & Srinivasan 2010).

This top-down activity of attention may ultimately promote the moment-to-moment awareness that is often reported by meditators and associated decreased tendencies for automatic responding (Quaglia et al. 2015). On the other hand, the paradigm used to access thisactivity was related to attention based in the working memory and executive control and this is not associated with neurophysiology of mindfulness state (Tang & POSNER 2009). Recently, EEG systematic review showed the same alpha and theta enhanced activity which related to a state of the relaxed alertness (Lomas et al. 2015).

Although attentional processing is mainly related to top-down modulation, few studies indicate that consciousness perception evoked by open monitoring may have a bottom-up modulation (Kerr et al. 2013; van den Hurk et al. 2010). This perception was associated with awareness of thoughts, emotion and non-judgmental proposed by mindfulness meditation. Some studies have shown sub-cortical activity for mindfulness experienced practitioners related to emotional or decision tasks. Bottom-up non-reactivity has been related to increased mental stability developed by robust structural changes (Chiesa et al. 2013; Lutz et al. 2008), such as changes in the insula (S. W. Lazar et al. 2005; S. Lazar et al. 2011). These neurobiological findings may correspond to the behavior of effortless awareness, as described by Jon Kabat-Zinn: “pay attention to whatever comes into your awareness. Whatever is a stressful thought, an emotion or body sensation, just let it pass in an effortless way, without trying to maintain it or change it in any way, until something else comes into your consciousness” (Kabat-zinn 1990).

The meditation improves attentional processing (Lutz et al. 2009; Zanesco et al. 2013) and electrophysiological studies have demonstrated that low-frequency activities. Specifically, Tanaka and colleagues (2014) found lower theta power for experience meditator when compared to the control group, and both presented a theta power increase during meditation. On the other hand, Lagopoulos and colleagues observed a decrease of the theta and alpha band after meditation. Low frequency theta and alpha band activity are related to relaxed attention patterns and are also associated with open monitoring mindfulness practice, defined as mindfulness of experience without a strict focus of attention on a particular object (e.g., the breath). On the other hand, few studies of gamma and mindfulness not yet clarified. Gamma oscillations are associated with many cognitive function as long-term memory, selective attention (Busch et al. 2006), high frequency gamma has been shown to predominate during periods of sleep and meditation, respectively, among experienced practitioners of mindfulness (Ferrarelli et al. 2013) and compassion (Lutz et al. 2004). Despite the lack of the high frequency (i.e. over 30 Hz) mindfulness studies, some studies have shown that increased gamma activity over frontal and parietal cortices during cognitive processing is related to greater conscious perception (Hauswald et al. 2015; Lutz et al. 2004), whereas a systematic review proposed by Lomas and colleagues had not observed consistent patterns in this frequency during mindfulness (Lomas et al. 2015), but this is observed out of the mindfulness practice but dependent of the years of practice (Berkovich-Ohana et al. 2012).

The fronto-parietal network (FPN) is associated with working memory (Olesen et al. 2004), visual perception awareness (Quentin et al. 2014), self-narrative (Vago & Silbersweig 2012) and sensory motor integration (Havranek et al. 2012). However, there is a lack of mindfulness studies that have examined the association between gamma activity in the FPN and mindfulness practice. The aim of this study was to investigate the differences in fronto-parietal gamma coherence (FPGC) between experienced meditators (EM) and non-meditators (NM). We hypothesized that EM, as compared to NM, would have greater frontoparietal gamma coherence before, during and after an open monitoring (OM) meditation practice. Furthermore, we hypothesized that electrophysiological differences would be a trait related to long-term meditation practice.

2. Material and methods

2.1. Participants

Twenty one participants were recruited: eleven experienced meditators (EM; 7 men, mean age 43.8 ± 17.53) and ten healthy controls with no meditation experience (i.e., non-meditators (NM); 5 men, mean age 40.10 ± 14.72). The group of EM included monks and laymen from various Buddhist traditions; they were recruited from three major meditation centers (i.e., Zen, Tibetan and Vipassana), localized around the Federal University of Rio de Janeiro (UFRJ). The group of NM were recruited at UFRJ. All the participants were contacted two weeks before starting the research. EM was defined as practicing regularly at least for the last five years (average of 12.23 years of practice ± 7.65 years) and living in the same city, under the same social and education condition and be exposed to the same environmental stimuli (i.e., they do not live isolated in Buddhist centers) of the control group. All participants were medication-free and had no sensory, motor, cognitive or attention deficits that could affect their performance. Subjects gave their written consent (according to the Helsinki Declaration) to participate in the study. The experiment was approved by the Ethics Committee of the Federal University of Rio de Janeiro under the number 01470112.0.0000.5263 (IPUB/UFRJ).

2.2. Task protocol

Subjects sat in a chair with a straight spine, in a darkened and noise-free room to minimize sensory interference. The subjects were asked to rest for 4 minutes (open eyes rest instructions were particularly emphasized for meditators: relax and refrain from entering the meditative state), and then they were instructed to perform open monitoring (OM) meditation for 40 minutes, followed by 4 more minutes of rest at the end. An auditory signal marked the beginning and end of each stage.

OM meditation instructions for EM and NM were: “pay attention to whatever comes into your awareness. Whatever is a stressful thought, an emotion or body sensation, just let it pass in an effortless way, without trying to maintain it or change it in any way, until something else comes into your consciousness”(Kabat-zinn 1990). Instructions were given at the beginning of the practice, as we believed this would promote better motivation as a first attempt of a new activity for the NM subjects. Due to its simplicity, the technique could be implemented by both EM and NM subjects and subjects in both groups reported no problems in following the instructions.

2.3. EEG recording

The International 10/20 EEG electrode system (Jasper, 1958) was used with a 20-channel EEG system (Braintech-3000, EMSA Medical Instruments, Brazil). The 20 electrodes were arranged on a nylon cap (ElectroCap Inc., Fairfax, VA, USA) yielding monopolar derivation using the earlobes as reference. The impedance of skin-electrode interface was kept between 5-

10 kΩ. The EEG signal was amplified, analogically filtered between 0.01 Hz (high-pass) and 80 Hz (low-pass), and sampled at 200 Hz. The *Data Acquisition Software* (Delphi 5.0) from the Brain Mapping and Sensory Motor Integration Lab, was employed with a notch (60 Hz) digital filter.

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2.4. Data analysis

Data analysis was performed by using MATLAB 5.3 (Mathworks, Inc.) and EEGLAB toolbox (http://sccn.ucsd.edu/eeglab). Visual inspection and Independent Component Analysis (ICA) were applied to remove possible sources of artifacts produced by the task (i.e., blink, muscle contraction). The data were collected using the bi-auricular reference and they were transformed (re-referenced) using the average reference after artifact elimination was conducted using ICA.

The signal was divided into segments of 6000 data points and each block corresponded to 30-seconds. Thus, the moments Rest 1 and Rest 2 consisted of eight blocks each. Regarding to meditation moment, the task lasted as long as 40 minutes (Kabat-zinn 1990; Segal et al. 2002; Soler et al. 2014), and we chose to analyze eight blocks (total of 4 min), corresponding to the moment between 20 and 24 minutes, which is consistent with the moment in which experienced meditators recognize entering a deeper state (Huang & Lo 2009).

The coherence (in its magnitude-squared form) in gamma band (30-100 Hz) (Buzsáki and Schomburg 2015; Madhavan et al. 2014; Perry et al. 2015; Velasques et al. 2013) was calculated as the ratio between the magnitude-squared Cross Spectrum Density between pairs of electrodes and the product of both Power Spectrum Densities. All spectra were estimated via Bartlett Periodograms based on the Discrete Fourier Transform (rectangular windowing), over 4-sec long segments for the derivation pairs Fp1-P3, Fp2-P4, F3-P3, F4-P4, F7-P3 and F8-P4. The final result was hence achieved from averaging coherence values throughout all frequency bins within the 30-100Hz range. Since each block consisted of 30 seconds, the calculation of coherence in gamma band considered seven excerpts for each block. Thus, the total data for NM group was 1440 (24 trials x 6 derivation pairs x 10 subjects) and for EM group was 1584 (24 trials x 6 derivation pairs x 11 subjects).

2.5. Statistical analysis

We performed a two-way ANOVA (2x3) to analyze the factors group (levels: EM x NM) and moment (levels: rest 1, meditation, rest 2) of gamma coherence for each electrode pair (Fp1-P3, F3-P3, F7-P3, Fp2-P4, F4-P4, F8-P4) separately. We performed a post hoc test (Bonferroni) when necessary. Examining the interaction, we conducted an one-way ANOVA to investigate the difference among moments (levels: rest 1, meditation, rest 2) for each group; and a T-test to show the differences between groups in each moment

3. Results

We analyzed gamma coherence for the Fp1-P3, Fp2-P4, F3-P3, F4-P4, F7-P3 and F8-P4 electrode pairs separately (i.e., intra-hemispheric frontoparietal region). The two-way ANOVAs revealed an interaction between the factors group and moment for Fp1-P3 (F=4.457; p=0.03), F7-P3 (F=5.264; p<0.01) (Figure 1a and 1b), F4-P4 (F=7,460; p<0.01) e F8-P4 (F=15.958; p<0.01) (Figure 2a and 2b). We performed a t-Test for independent samples between groups for each moment, and an one-way ANOVA among moments for each group to investigate the interaction. Examining the deviations Fp1-P3, Fp2-P4, F3-P3 and F7-P3, EM group showed higher coherence than NM in rest 1, meditation and rest 2. Examining the deviations F4-P4 and F8-P4, EM group showed higher coherence in rest 1 and rest 2. The one-way ANOVA showed a difference between rest 1 and meditation, and meditation and rest 2 for the electrodes pairs Fp1-P3 and F7-P3. Specifically, we found lower gamma coherence for meditation when compared to the other moments. Regarding the NM group, we did not observed no significant difference among moments. Examining the deviation F4-P4, we observed differences for EM group between rest 1 and meditation; and meditation and rest 2. Specifically, we identified lower gamma coherence for meditation when compared to the other moments. Regarding the NM group, we found difference between meditation and rest 2, with lower gamma coherence in rest 2. For F8-P4, we detected differences for EM group between rest 1 and meditation; and between rest 1 and rest 2. Specifically, we found lower gamma coherence for meditation when compared to rest 1, and lower rest 2 when compared to rest 1, respectively. For the NM, we observed differences between rest 1 and meditation; and between meditation and rest 2. Specifically, we identified higher gamma coherence for meditation when compared to the other moments.

We also observed a main effect for group over F3-P3 (F=22.329; p<0.01) and Fp2-P4 (F=13.622; p<0.01) (Figure 3a and 3b).

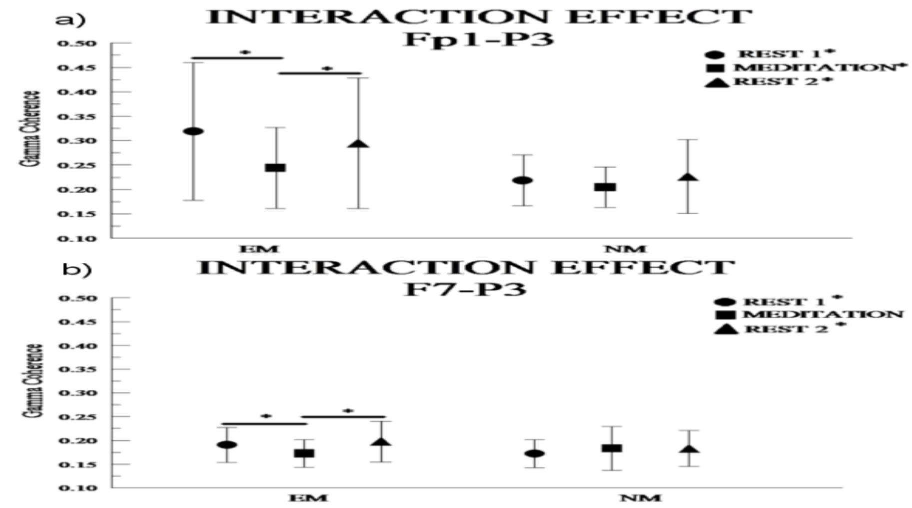

Fig 1. – ANOVA 2x3 (group x moment) interaction effect of the left fronto-parietal network. The marks (●,■,▲) represent gamma coherence mean and the vertical lines represent standard. The horizontal lines means the significance (p<0.05) between moments (rest 1, meditation, rest 2) and the astheristics mark (*) in moment mark represent significance difference (p<0.05) between groups for each moment. (a) Mean and standard deviation for Fp1-P3. (b) Mean and standard deviation for F7-P3.

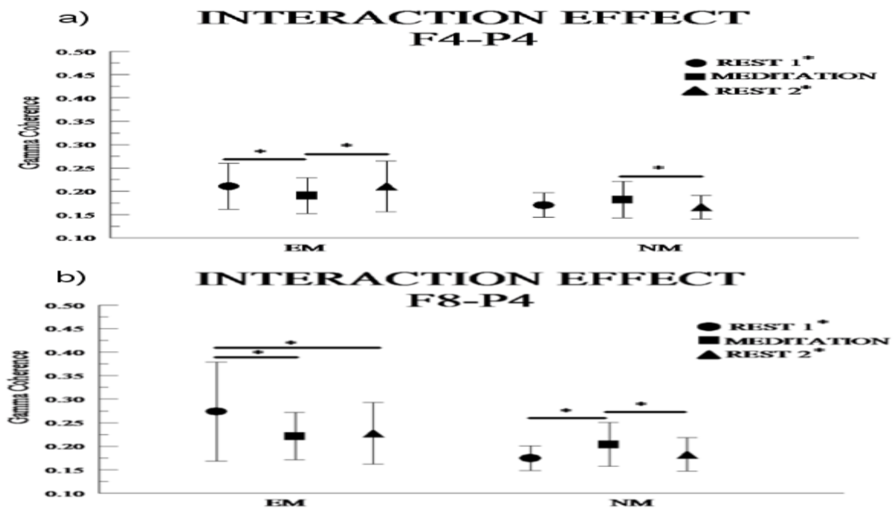

Fig 2. – ANOVA 2x3 (group x moment) interaction effect of the right fronto-parietal network. The marks (●,■,▲) represent gamma coherence mean and

the vertical lines represent standard. The horizontal lines means the significance (p<0.05) between moments (rest 1, meditation, rest 2) and the astheristics mark (*) in moment mark represent significance difference (p<0.05) between groups for each moment. (a) Mean and standard deviation for F4-P4. (b) Mean and standard deviation for F8-P4.

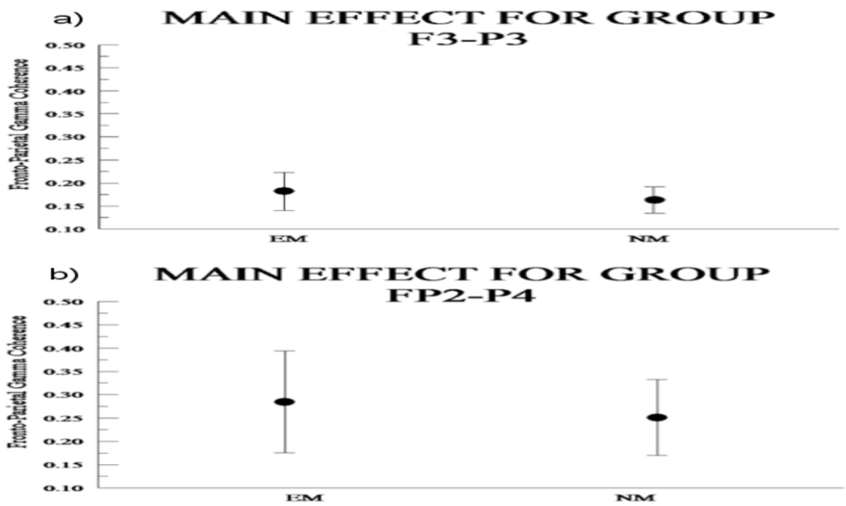

Fig 3. – Main effect for groups in the fronto-parietal gamma. (a) mean and standard deviation for F3-P3. (b) mean and standard deviation for Fp2-P4.

4. Discussion

The present study aimed to clarify the neurophysiology of gamma coherence in the fronto-parietal network (FPGC) before, during and after OM meditation. This network is related to working memory (Olesen et al. 2004), visual perception awareness (Quentin et al. 2014), self-narrative (Vago & Silbersweig 2012) and sensory-motor integration (Havranek et al. 2012) tasks. On the other hand, gamma is a high frequency band associated with memory and attention (Benchenane et al. 2011), associative learning (Miltner et al. 1999), consciousness (Cavinato et al. 2015; Light et al. 2006) and meditation (Travis & Shear 2010). Particularly, coherence is a coupling measure between areas showing the relative strength between two electrodes (Babiloni, Ferri, et al. 2006); increase in gamma coherence between two areas is related to an improvement of frontal and parietal coupling and integration.

We suggested this coupling as associated with the way of attention is processed. Therefore, mindfulness is related to an attention of the present moment without judgment with openness and intention (Kabat-zinn 1990) and studies have shown the differences between experienced meditators and novices related to attentional processing (Chiesa et al. 2013; Kerr et al. 2013; Quaglia et al. 2015; van den Hurk et al. 2010). Basically, mindfulness has been associated with top-down and bottom-up processing and these differences were related to the time of practice (Chiesa et al. 2013). On the other hand, novice needs to sustain his attention in the specific object (e.g. breathing, body) to identify the moment of the mind wandering (Malinowski 2013). This training improves the focused attention and has been associated with top-down pathway processing (Kerr et al. 2013). The studies of this processing in the FPGC are scarce. Even though, a study with disorder of consciousness (i.e. minimally conscious state) had an enhancing of the FPGC after stimulation which showed an association with the aware and cognitive process (Naro et al. 2015).

This top-down processing is related to self-control of attention to maintain a focus strictly in the specific object and this is the robust way to improve attention and perceive distraction (Brefczynski-Lewis et al. 2007). Moreover, mindfulness is associated with openness and intention attitude without wander. However, this training increases the conscious of the body sensations as experience without judgment (Fox et al. 2012; Jha et al. 2007; Jo et al. 2015).

At this point of view, the awareness of the sensations promotes a different attentional processing by the bottom-up pathway which is associated with experienced meditators (Tanaka et al. 2015; van den Hurk et al. 2010). The time of mindfulness meditation practice is a relevant factor to define which pattern of attention is used by practitioners (Chiesa et al. 2013). Our result demonstrated that EM presents a specific fronto-parietal gamma coherence pattern related to long-term training. We observed that EM exhibited decreasing fronto-parietal gamma coherence during mindfulness when compared to NM. These results support the hypothesis that meditation training is associated with the development of the neural networks necessary for improving attention (Grill-Spector et al. 2006; Posner et al. 2015).

The main result was the interaction between group (EM x NM) and moment (rest 1, meditation, rest 2) for pair of electrodes in the right hemisphere (F4-P4 and F8-P4) and the left hemisphere (Fp1-P3 and F7-P3). Specifically, gamma coherence was found for pairs Fp1-P3 and F7-P3 and both pairs showed difference in moment only for EM. We hypothesized that EM, as compared to NM, would have greater FPGC during open monitoring (OM) meditation practice, which was supported by the fact that NM presented the same pattern of FPGC during all tasks, whereas we found lower gamma coherence for EM during meditation when compared to rest 1 and res 2.

Moreover, when EM were out of the meditative state, they showed higher fronto-parietal coherence, possibly due to the minimized elaboration of the OM task. This process seems to not change for EM in the right hemisphere, maintaining the same pattern of the left side, differently from the NM. The altered oscillatory pattern was found for NM when it was compared to meditation between pre and post rest moments. These findings may be explained by the NM subjects having no familiarity with the task and thus evoking more working memory activity to recover the task information (Babiloni, Vecchio, et al. 2006). Thereby, the NM subjects may have experienced a more frequent inner speech process (i.e. mind wandering). We hypothesized as a mental state for NM during OM practice, due to their maintenance of focused attention in order to be more open to the experience (Chiesa et al. 2013).

The hypothesis that the NM needed to recover the task information during OM (Babiloni, Vecchio, et al. 2006) was further supported by higher coupling of the right FPGC during mindfulness meditation (F8-P4 pair) and its decreased after this practice (F4-P4 pair). Notwithstanding, higher frontal activity (i.e. working memory) can be activated by a mechanism related to sensory representation of the inner and outer information (Cavinato et al. 2015), in view of the long practice without moving (40 minutes), as well as self-narrative increase (Morin & Michaud 2007; Mu & Han 2010). On the other hand, no alterations were observed in the left side (Fp1-P3 and F7-P3 pairs) due to this area being associated with cognition/memory without changes between rest and practice (Becerra et al. 2014; Smith et al. 2009). This supports the choice of delivering the task information right before the practice in order to increase motivation with minimal interference as shown in the FPGC pattern of the EM.

In addition to the influence of the practice in the left x right fronto-parietal network, our results also show greater consistency in range for EM, compared to the NM group. Studies have shown that such influence is the integration of the frontal and parietal areas based on the attention quality according to the practitioner level, in other words, more experienced practitioners tend to require less brain activity for a task associated with experience level (Saggar et al. 2012; Slagter et al. 2011). This occurs due to lower frontal activity for the wide attention differently from the strict focused attention (Chiesa et al. 2013; Tanaka et al. 2014). This aspect is in agreement with our results where the EM had shown greater FPGC when compared to NM, even though out of practice. Thereby, we suggest this higher FPGC to be a better neurophysiological biomarker of the fronto-parietal coupling.

We suggest that this learning promotes an improved neural efficiency during the OM practice, as shown previously (Bishop, Duncan, Brett, & Lawrence, 2004). Furthermore, the EM may show higher coherence for every moment when compared to NM due to higher integration of the inner and outer sensations promoted by non-conceptual self-awareness (Vago 2014). This interpretation should be cautioned by the limitation of the NM group not having prior experience with OM meditation, leading to increase in the FPGC of the right side associated with a more specific focused attention among the NM group during OM meditation (Babiloni, Vecchio, et al. 2006; Chiesa et al. 2013). In general, the lack of random assignment to meditation experience and the cross-sectional nature of the design are major limitations of the current study.

The major finding of this study was the fact of the EM showing higher fronto-parietal coupling even with lower coherence during OM meditation, when compared to NM. We hypothesized this finding to be connected to a decrease in the attentional interference process (i.e. inner speech, self-narrative, thoughts), as well as to greater wandering and non-judgment perception before returning to the attentional process (Brown & Jones 2010; Cahn et al. 2012; Farb et al. 2007; Morin & Michaud 2007). Better coupling during OM meditation is a specific trait of EM, because of their regular training. Thus, the regular practice of EM seems to have the power to promote better FPGC potentiating it during events outside the OM (i.e. rest), where there are more cognitive activities (ie working memory, Default Mode Network), as occurs in NM during the OM practice.

5. Conclusion

In summary, FPGC is a great pathway to understand the neurophysiology of attention concerning the OM meditation practice. The long lasting training is able to improve gamma coherence of the fronto-parietal area only at rest but decrease in FPGC was observed during the practice, suggesting low frontal coupling with posterior area promoted by experience level among the EM group. The data was supported by the unchanged left fronto-parietal gamma coherence and increased in FPGC for the right hemisphere in NM.

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CAPÍTULO 5 - CONCLUSÃO

A meditação é uma prática capaz de potencializar os efeitos benéficos da atenção, visto que seu objetivo é a elaboração de pensamentos sem ruminação ou qualquer envolvimento emocional, tornando melhor e mais rápido a resposta de novos estímulos, gerando um aumento na concentração e aprendizado. Isto acontece, proporcionalmente ao tempo de prática e ao tipo de meditação, já que na mindfulness é possível uma maior ativação de frequências mais altas (gama) que estão relacionadas a uma melhor percepção da consciência. Nos estudos mais atuais é possível verificar uma melhor explicação metodológica, principalmente relacionado a prática e tipo de pesquisa.

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