International Journal of Transpersonal Studies

Volume 40
Issue 1 *Iss. 1 (2021)*

Article 7

9-1-2021

Brain Activity During Paired and Individual Mindfulness Meditation: A Controlled EEG Study

Hessel Engelbregt
Hersencentrum Mental Health Institute, Amsterdam, The Netherlands

Hugo F. Alderse Bass
Section Clinical Neuropsychology, Vrije Universiteit, Amsterdam, The Netherlands

Sietske de Grauw
Section Clinical Neuropsychology, Vrije Universiteit, Amsterdam, The Netherlands

Jan Berend Deijen
Section Clinical Neuropsychology, Vrije Universiteit, Amsterdam, The Netherlands

Recommended Citation

Engelbregt, H., Alderse Bass, H. F., de Grauw, S., & Deijen, J. B. (2021). Brain activity during paired and individual mindfulness meditation: A controlled EEG study. *International Journal of Transpersonal Studies, 40* (1). https://doi.org/https://doi.org/10.24972/ijts.2021.40.1.45

Brain Activity During Paired and Individual Mindfulness Meditation: A Controlled EEG Study

Hessel Engelbregt
Hersencentrum Mental Health Institute
Amsterdam, The Netherlands
Department of Psychiatry and Psychotherapy
Ludwig-Maximilians-University of Munich
Munich, Germany

Sietske de Grauw
Section Clinical Neuropsychology
Vrije Universiteit
Amsterdam, The Netherlands

Hugo F. Alderse Baas
Section Clinical Neuropsychology
Vrije Universiteit
Amsterdam, The Netherlands

Jan Berend Deijen[1]
Section Clinical Neuropsychology
Vrije Universiteit
Amsterdam, The Netherlands
GGZ
Amsterdam, The Netherlands

Objective: In this study, we evaluated brain electroencephalographic (EEG) activity in healthy participants during the performance of paired and individual mindfulness meditation (MM). We hypothesized that EEG activity is differentially affected by meditation in pairs compared to individual meditation.
Methods: A total of 20 healthy female university students (mean age 19.54 years, SD =1.53) with no prior experience in MM participated in this study. All participants had to perform a 5-minute MM task together and individually while the other participant was in rest or performing a concentration task (control condition). To exclude social interaction as main factor, participants were separated from their research partner by an opaque screen while instructions were given through headphones. Brain electroencephalographic (EEG) activity from each individual student was measured during all conditions.
Results: The main findings indicate that left-frontal alpha and theta spectral EEG power was significantly higher during the paired MM condition compared to individual MM and control condition.
Conclusions: This controlled MM study demonstrates differences in brain activity between practicing mindfulness in pairs compared to practicing it individually. We conclude that the increased alpha and theta EEG power during paired MM may be associated with social facilitation or the activation of "theory of mind." The results invite further reflection on interpersonal communication and mindfulness.

Keywords: ***mindfulness meditation, individual meditation, paired meditation, EEG, theory of mind, brain activity***

Mindfulness meditation (MM) is an increasingly applied type of training or therapy in the Western world. The usefulness of MM has been studied across various populations, including cancer patients (Ho et al., 2017), cardiac patients (Zieff, 2017), healthcare professionals (T. Lomas, Medina, Ivtzan, Rupprecht, & Eiroa-Orosa, 2018) and lawyers (Minda, Cho, Nielsen, & Zhang, 2019). Most studies use MM to reduce stress as an alternative therapy for Western healthcare (Hilton et al., 2017), whereas some research is focused on the kind of processes MM alters in the brain (Cahn & Polich, 2006; Chiesa & Serretti, 2010). Meditation is sometimes linked to attention and concentration to the inner self, which ultimately generates a present-moment experience (Kabat-Zinn, 1994). In academic literature about meditation, the term *meditation state* refers to the altered sensory and metacognitive awareness that can arise during meditation practice and the term *meditation trait* refers to the lasting changes that persist in the practitioner irrespective of being actively engaged in meditation (Shapiro & Walsh, 1984). Improvement of attention and well-being, as

https://doi.org/10.24972/ijts.2021.40.1.45

well as reduced stress and depression, have been found in meditators who meditate for at least a couple of years (Cahn & Polich, 2006). Although self-awareness may increase, it is not clear whether self-referential awareness is an essential aspect in improvement of attention and reduction of stress and depression. Rather, with time and practice, metacognition may increase, but self-centeredness is purported to decrease (Dahl, Lutz, & Davidson, 2015).'These findings are less clear in short-term MM, where most meditators are new to meditation or just meditate to participate in a research study.

In contrast to the reported positive benefits, MM can have concerning side effects. For instance, a cross-sectional study on the effects of intensive and long-term meditation reported that over 60% of individuals had at least one unwanted effect, such as increased anxiety, depression and even full-blown psychosis (Shapiro Jr, 1992), These adverse effects may be induced by the awareness of difficult feelings or the exacerbation of psychological problems (Tim Lomas, Cartwright, Edginton, & Ridge, 2015). Indeed, emotional difficulties have been reported in people practicing MM. In one study, an 8-week mindfulness-based stress reduction (MBSR) course appeared to increase stress and depression in some of the participants (Dobkin, Irving, & Amar, 2012). In addition, an experimental study on a short MM intervention with healthy individuals led to increased biological stress when compared with a control group (Creswell, Pacilio, Lindsay, & Brown, 2014). More recently, from 342 meditation practitioners 25.4% reported unwanted effects with varying severity, which were mostly transitory and related to individual practice (Cebolla i Martí, Demarzo, Martins, Soler, & García Campayo, 2017). Because of the small number of studies on adverse effects and the above cited relationship with individual practice, it remains unclear whether mindfulness per se can lead to negative health outcomes. It may be that a lack of understanding of the nuances of mindfulness among some instructors and associated poor teaching of mindfulness might pose the greatest risk to patients (Van Gordon, Shonin, & Garcia-Campayo, 2017).

In addition to conflicting data on benefits and unwanted effects, it should be noted that scientific data on mindfulness are still scarce and conflicting. Many of the studies on mindfulness and meditation are poorly designed, lacking a control group and compromised by inconsistent definitions of what mindfulness actually is (Van Dam et al., 2018). Currently there is an increase in neuroimaging measures to clarify the neural activity associated with practicing mindfulness. However, as there are mostly no effect sizes calculated, the MM-induced effects on the brain compared to other cognitive training methods regarding diagnostic and/or therapeutic utility is still indefinable (Castellanos, Di Martino, Craddock, Mehta, & Milham, 2013).

MM has been reported to result in an unique psychophysiological response, measured as electrocortical activity (Schuman, 1980). In particular, studies reported increased alpha and theta activity in electroencephalography (EEG) during MM. For example, in experienced MM practitioners, increased alpha power was found in posterior regions and increased theta power in frontal and temporal-central regions, compared to a quiet rest condition (Lagopoulos et al., 2009). Furthermore, increases in both alpha and theta activity were found after 10 sessions of meditation, where theta activity was found during every stage of meditation and alpha activity only during a deeper stage of meditation (Tsai, Jou, Cho, & Lin, 2013). Increased theta activation has been found to be linked to activation of the frontal cortex and the anterior cingulate cortex (ACC) during the performance of attention and memory tasks, including a visual short-term memory task, a counting task, a visual memory task and a breathing exercise. Results indicated that in all tasks theta activation was increased in the frontal cortex and the ACC (Asada, Fukuda, Tsunoda, Yamaguchi, & Tonoike, 1999). In a more recent study EEG amplitudes in 61 university students that were randomized to a 15-min single-session MM (n = 24), neurofeedback (n = 17), or sham-neurofeedback training (n = 20) were compared. After one session a higher global full-band alpha amplitude in MM as well as in neurofeedback participants was found compared with the alpha amplitude in sham-neurofeedback participants (Chow, Javan, Ros, & Frewen, 2016). The researchers suggested that the absence of an increase in alpha power after MM relative to neurofeedback training might be due to the lack of multiple sessions. However, other studies do show effects of short-term MM on attention. In a study of four 20-minute sessions of MM on separate days, an MM training group (n=24) was compared to a group listening to an audiobook (n=25). After four days, the MM-group showed improved sustained attention compared to the control group (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). In another study (Tang et al., 2007), over a period of five days, 40 participants were given a short 20 minute MM training and another 40 participants practiced a form of progressive relaxation training (Bernstein & Borkovec, 1973). After 5 days of training, participants who meditated significantly increased their executive attention, as measured with the Attention Network Test (Macleod et al., 2010). However, no significant effects were found between the experimental and control groups, which the authors explained by the fact that the control group also received a relaxation training. In a 2011 study by Kerr et al., 6 students underwent a MM instruction and practiced MM daily for 8 weeks, while in the control condition 6 students were instructed not to meditate. MM participants showed increased alpha (9-10 Hz) modulation, which is linked to attentional processes (Kerr et al., 2011).

The literature suggests that MM can be helpful for personal as well as group purposes. In practice, MM is prescribed for several reasons by therapists, coaches, teachers and also by sports (e.g., running, basketball) trainers. There could be several reasons for one to choose for single or group MM. However, MM is mostly practiced in group-form as practitioners argue that group mindfulness makes you more connected to others, creating a sense of harmony. Indeed, humans are social creatures with a natural desire for social interaction. When two individuals interact, they continuously and mutually adapt their own actions to the actions to those of their partner, ultimately leading to become a coupled unit (Baumeister & Leary, 1995). It is known that task performance can be influenced merely by the presence of another person, who does not need to be an active cooperater but may be a passive spectator. In case of improved performance this phenomenon is called social facilitation (McLeod, 2011). Factors that may explain the occurrence of social facilitation are 1) attention conflict, which motivates a person to pay more attention to the task than to the other person (Baron, 1986), 2) the fear of being appraised by the other person (Cottrell, Wack, Sekerak, & Rittle, 1968), and 3) increased arousal by the presence of others, which may improve performance of easy tasks (Zajonc & Sales, 1966).

In contrast, if the presence of another person impairs the quality of one's task performance, the phenomenon is called social inhibition. It has been found that social inhibition, i.e. impaired performance in the presence of others, occurs while performing a novel or difficult task (McLeod, 2011).

Social cooperation of people may give rise to a mental process of adjusting our behaviour to that of our partner(s) because of the shared goals to which participants are committed. It is possible that in this mental process "Theory of Mind" (ToM) may play a role (Baron-Cohen, 1997; Decety & Sommerville, 2003). With respect to brain activity, upon activation of the ToM a specific brain network has been found to become active, including the medial PFC and the temporal-parietal junction (Schurz, Radua, Aichhorn, Richlan, & Perner, 2014).

Study

The aim of the present study was to examine whether brain activation is differentially affected by (being aware of) paired meditation compared to individual meditation and a control condition, and if ToM may be involved in paired meditation. Notably, we deliberately designed that during paired meditation participants were aware of the the other meditating person to allow for an (unconscious) adjustment to the presence of the other person, which might be accompanied by ToM activation. As it was not our purpose to examine the occurrence of electromagnetic resonance or standing waves between the two participants, we explicitly did not rule out the perception of auditory cues induced by the other person (see Fig. 1 for flow chart of study design).

While Mantzios & Giannou (Mantzios & Giannou, 2014) examined possible advantage of meditating as a group, it remains unclear whether social interaction or meditation is the main factor to induce a specific state of consciousness. To exclude

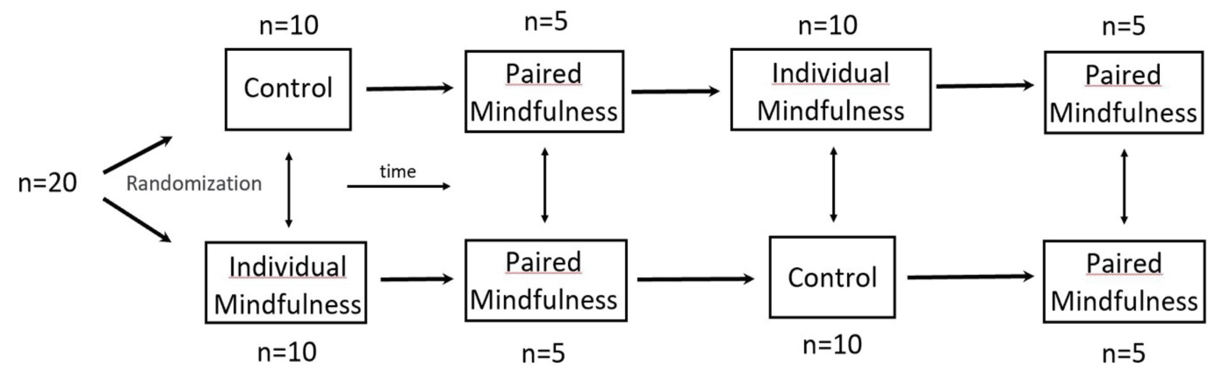

Fig. 1. ***Flow chart of study design***

social interaction as the main factor, participants in this study were separated by an opaque blue wooden screen while instructions were given via headphones. As we aimed to examine whether ToM may play a role during paired meditation, participants were informed whether the paired participant was also meditating or not. It was hypothesized that frontal as well as temporal theta and alpha would particularly increase after practicing paired MM in comparison with individual MM and the control condition.

Participants

A total of 22 healthy subjects (21 women, 1 man) signed up for this study. They enrolled via an online student subject pool ("Sona-systems Ltd.," 1997-2019). All participants were first year Psychology students of the Vrije Universiteit in Amsterdam, The Netherlands. Participants were mostly college friends or acquaintances, signed up as a pair, had no experience in meditating, and were compensated with elective credit points for participation. Other a priori exclusion criteria were hearing problems and physical disorders that could interfere with EEG measurement or for which EEG could pose a health risk (e.g., epilepsy). Thus, all included participants were assumed to be healthy enough to participate in an EEG study and were able to listen to spoken instructions. Participants' mean age was 19.54 years (SD =1.53). For personal reasons, two persons (including the only man) dropped out. The data of the 20 remaining subjects were analysed. The study was approved by the Scientific and Ethical Review Committee (VCWE) of the Faculty of Behavioural and Movement Sciences of the Vrije Universiteit Amsterdam.

EEG recordings

EEG was recorded by means of two Deymed Truscan 32-channel systems in combination with Deymed 19-channel electrode caps and ear clips. Electrode skin impedance was less than 8 kΩ. The electrodes were placed according to the International 10/20 system (Jaspers, 1958). An electrode at Fpz served as the ground electrode. Each participant was connected to a separate EEG device. The two EEG systems were connected to two portable computers with a standard Windows 10 operating system.

Procedure

After setting up the EEG devices, the participants were asked to plug in their earphones. Thereafter, they performed either paired MM, individual MM or a control condition. The MM was induced by a pre-recorded guided mindfulness meditation translated in Dutch, called the "Three minutes breathing space" (Segal, Williams, & Teasdale, 2002) with a two minute introduction, containing a general instruction to concentrate on oneself while sitting comfortably and to be aware of one's feelings and external sounds. The five minutes introduction and practice were recorded by a Dutch female voice (Stiny-Coops, 2008). Participants were sitting straight up in a chair while the recorded voice told them what to do in a peaceful tone of voice. The participants were instructed to focus on everything they experienced, including momentary thoughts, their mood, and physical sensations, and were instructed to try to put words to their experiences in their mind, and then just to let these thoughts be as they were. After one minute of silence and another minute of silently focussing on their breath, the subjects were instructed to focus their attention on their whole body. During the final part of the recording, participants were instructed to focus their attention on any feelings of discomfort, tension or resistance in the body. Subjects were instructed to breathe in and to try to get the air towards that 'problem point', and were instructed to try to 'soften' that 'problem point' on the outbreath. Participants were instructed to be open to everything they felt without judgment, and to just let it be.

While undergoing the individual condition, participants sat on the same chairs that were used during the paired MM condition. During this part of the experiment, one of the pair was instructed to practice MM while the other one was merely instructed not do anything for five minutes, or to perform a concentration task. We included this concentration task as second order control condition because there is still debate whether MM can be characterized as a relaxation or as a concentration task. To avoid comparing MM with a similar task as control the condition was averaged across rest and concentration, to eventually establish an intermediate control condition.

In summary, there were three conditions in counterbalanced order: paired mindfulness, individual mindfulness (one MM, one rest) and a an individual control condition (one MM, one concentration). During all sessions, participants were sitting next to each other, separated from each other by means of an opaque screen (2 x 2 m).

In the concentration task, the participants heard a series of 33 numbers within a duration of 5 min. They were instructed to count how many numbers they heard. A number consisting of two numerals, such as 23, was to be counted as one number. After finishing the task, participants were asked to say their answer aloud. We did not evaluate whether the subjects answered correctly, because the only purpose of this task was to have participants concentrate. In the rest condition, the subjects were instructed to do nothing for 5 minutes.

EEG Recordings, Selections and EEG Transformations

Concerning the quantitative analyses, Linked Ears (LE) reference, which is the most common used EEG montage and well described in a paper of Lopez et al. (Lopez et al., 2016) was used for the comparison between conditions. Prior to both analyses, EEG recordings were screened by a neurologist for seizure activity and/or other abnormal EEG patterns. There were no signs of any abnormality in the recordings. Artefact-free EEG data were selected for further analysis. Data of EEG recordings were included only when there was a minimum of 20 sec artefact free data. Absolute Power for 4 quadrants (Q, left frontal, right frontal, left temporal and right temporal) and coherence values for, F3, F4, T3 and T4 were analysed by means of the automated FFT tools in the digital program Neuroguide (Version 2.9.4) (Thatcher, 2008). The four Q's were calculated by summarizing absolute values for respectively FP1, F3 (Q1; left frontal), FP2, F4 (Q2; right frontal), T3, T5 (Q3; left temporal) and F4, T6 (Q4, right temporal). Outliers (>2 SD of average power per frequency-range and location) were ignored (a total of 0.5% of the database).

LORETA analysis

A surface recorded scalp EEG with eyes closed was used for a 3D current density analysis using the LORETA package v20150415. LORETA estimates the current source density (μV/mm^2) distribution of each voxel at 5mm spatial resolution (low resolution) in the Talairach/MNI space. A detailed description of the sLORETA method is provided by Pascual-Marqui (Pascual-Marqui, 2002). The scalp EEG was segmented into 2s segments and converted into cross spectrum files for the discrete frequency range of 4–8 Hz, 8–12 Hz, 12–25 Hz and 4–25 Hz using the sLORETA transformation matrix in order to convert the electrical scalp activity into standardized current density in the cortex. Allowing for the variability of structural brain tissue and conductivity levels in small sample sizes, we used a subject-wise data normalization to eliminate a global source of variability. All 20 subjects were included for the comparison of EEG recordings during individual and paired MM. The statistical comparisons were done using the implemented statistical nonparametric mapping tool. The statistical level was set at $p < .05$.

Statistical Analyses

To test for differences between paired MM and both individual MM conditions we applied repeated measures ANOVA with Condition (3 levels) as within subjects factor. As paired comparisons planned repeated contrasts were applied. Bonferroni correction was applied to correct for multiple testing, with a corrected alfa of .004 (.05/8). The absolute spectral power values at frontal and temporal areas at left and right side (Q1–Q4) during paired MM were compared with those during both individual MM conditions. We did not rule out demographic variables because the group of participants was homogeneous concerning gender (all females), meditation familiarity (not any) or age (first year students with a mean age of 19.54 years, SD =1.53). To ascertain that our 20 participants provided enough power to (dis)confirm the hypotheses, we conducted a power analysis using the program G* power 3.1.9.4 (Faul, Erdfelder, Lang, & Buchner, 2007). After applying an effect size *partial* η2 = 0.2 (similar to f = 0.5), correlation = 0.5, and 3 measurements, the obtained power was 0.93 for sample size = 11.

Results

Differences between individual and paired mindfulness meditation (MM) were examined in terms of EEG power and source density distribution.

EEG Power During Paired MM Compared with Other Conditions

Left-frontally, theta activity was significantly different between the three conditions, $F(2,32) = 3.87$, $p = .031$, *partial* $\eta^2 = .19$ (Greenhouse-Geiser). Planned repeated contrasts indicated that theta activity was higher during the paired MM condition compared to the individual condition $F(1,16) = 11.81$, $p = .003$, *partial* $\eta^2 = .42$. In addition, left–frontal alpha was different between the three conditions $F(2,18) = 11.69$, $p = .003$, *partial* $\eta^2 = .41$ (Greenhouse-Geiser). Planned repeated comparisons indicated that left-frontal alpha activity was significantly higher during the paired MM condition compared to the individual condition, $F(1,17) = 11.82$, $p = .003$, *partial* $\eta^2 = .41$, and compared to the control condition, $F(1,16) = 11.81$, $p = .003$, *partial* $\eta^2 = .42$. All results of planned comparisons of EEG power across the three conditions are shown in Table 1. These results were significant after Bonferroni correction.

The calculated correlations between EEG power of significant results were high and almost all significant, indicating a high interdependency between the dependent variables (Table 2).

sLORETA Results

The sLORETA analyses revealed a significant increase in the alpha band (8–12 Hz, Fig. 2) for the comparison of paired MM versus individual MM in frontal brain regions, the Middle and Superior Frontal Gyri (estimated Brodmann Areas 10 and 11).

Discussion

During meditation negative effects for theta (Amihai & Kozhevnikov, 2014; Cahn & Polich, 2006; Lagopoulos et al., 2009; Lehmann et al.,

		Paired MM		Individual MM		Control					
		M	SD	M	SD	M	SD	p^1	ES[1]	p^2	ES[2]
LF	Theta	14435824,86	9920436,31	8526058,31	5245140,48	11551097,29	5643737,06	**.003**	.425	.294	.07
RF	Theta	10321414,54	10864006,72	8949951,55	5599395,46	11715354,23	5453902,71	.424	.04	.648	.01
LT	Theta	10057869,05	12724001,27	9633860,44	6426285,979	7411961,35	4823161,61	.867	.00	.428	.04
RT	Theta	11947685,00	11947685,00	10016572,94	5277559,14	8075478,35	5918078,81	.384	.04	.256	.08
LF	Alpha	29533860,14	27903946,56	11202370,44	8289726,22	11073770,72	7738368,88	**.003**	.41	**.003**	.41
RF	Alpha	12270108,25	13360920,80	11040277,33	7885073,13	11043656,88	7668962,34	.442	.35	.558	.02
LT	Alpha	8725510,47	12649514,25	15452179,08	15070780,94	15252252,16	16850311,62	.04	.23	.114	.14
RT	Alpha	19391554,44	24408782,81	26064777,34	24697264,57	24284329,10	23823067,19	.081	.16	.237	.08

Signicant differences are in presented in bold. MM = mindfulness meditation. M = mean, SD = standard deviation. P1 ES1: Paired MM versus Individual MM… P2 ES2: Paired MM versus control. ES = effect size; partial η2
L= left, R = right. F = frontal, T = temporal

Table 1. ***Mean and SD of EEG power under the three conditions***

	LF alpha	LF theta2	LF alpha2	LF theta3	LF alpha 3
LF theta	.69**	.83**	.31	.58*	.46*
LF alpha		.34	.71**	.77**	.89**
LF theta2			.47*	.65**	.77**
LF alpha2				.68**	.71**
LF theta 3					.76**

* p < .05 ** p <.005 2 = individual 3 = control

Table 2. Pearson correlations between EEG power of significant effects

2012) and alpha (Amihai & Kozhevnikov, 2014; Berkovich-Ohana, Glicksohn, & Goldstein, 2012; Cahn & Polich, 2006; Lehmann et al., 2012) spectral EEG power have been found. On the contrary, also positive effects for theta (Cahn & Polich, 2006; Lagopoulos et al., 2009; Lehmann et al., 2012; Tim Lomas, Edginton, Cartwright, & Ridge, 2014; Takahashi et al., 2005) have been reported. Notably, the current study confirms literature, which suggests an increase of alpha and theta (Cahn & Polich, 2006; Lagopoulos et al., 2009; Takahashi et al., 2005) activity (EEG power) during meditation. In the present study, however, this increase occurs left frontally for alpha and theta activity, only when meditating together. Although an increase in alpha and theta activity during MM could be expected from some previous studies, it is remarkable that in the present study this increase occurs after a very short instruction to participants with no previous experience in meditation. Our study seems to support the idea that MM is more than mere relaxation. Interestingly, in the current study, only practicing MM together increased left-frontal alpha and theta EEG activity. The latter is in accordance with Mantzios et al. (Mantzios & Giannou, 2014). However, it is contrary to the recent findings of Matiz et al. (Matiz, Fabbro, & Crescentini, 2017), who found no specific benefit of meditating in groups compared to individual meditation. For the present results, implying that the knowledge to meditate with someone else increases specific brain activity, various explanations may be valid. Although participants were separated by a screen, the merely knowledge of the presence of another person practicing MM may have caused social facilitation (McLeod, 2011), increasing the effects the MM practice as a result of higher arousal (Zajonc & Sales, 1966). Another explanation might be the activation of ToM. The shared goal of people who are meditating together may have led to adjusting their meditation effort to each other, thereby increasing the activity of the prefrontal cortex (Baron-Cohen, 1997; Decety & Sommerville, 2003). Although it was not our purpose to examine, it may yet be the case that transpersonal processes have been occurred. Thus, separate from social facilitation or theory of mind, the increased brain activation while practicing MM in pairs may just be the result of expanded consciousness beyond the usual ego boundaries and the limitations of time and space

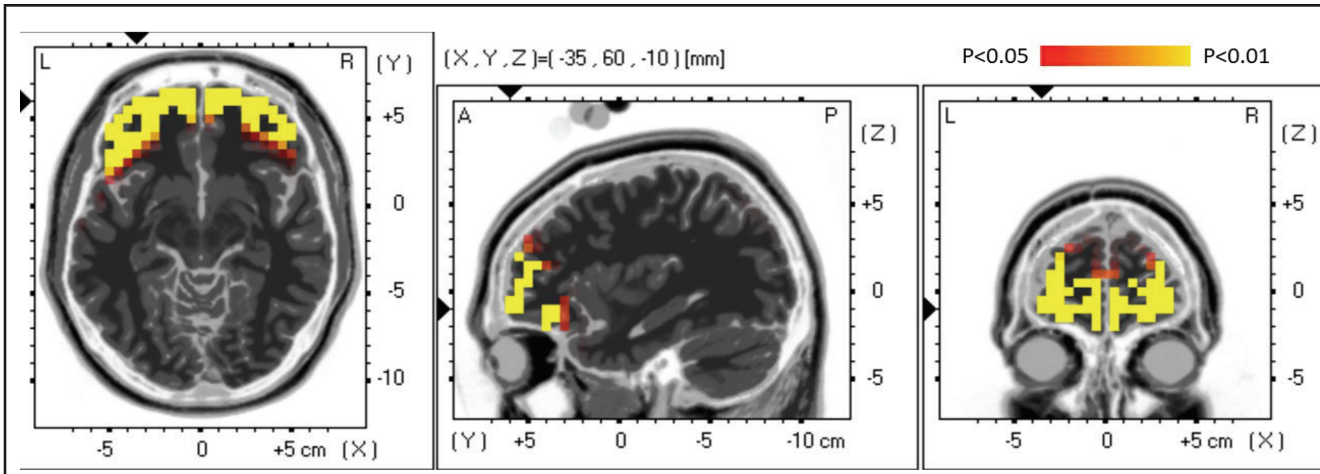

Fig. 2. *Results of sLORETA analysis for 8-12 Hz. activity. An increase of 8-12 Hz activity is revealed during paired Mindfulness compared to individual Mindfulness.*

(Grof, 2016). It has been argued that transpersonal and extra-sensory events such as intuition might be associated with a multidimensional space/time brain structure, being open to external electromagnetic and quantum fields (Meijer, 2014). Thus, two meditating minds, being part of a universal quantum field, may be connected by electromagnetic fields, reflected by resonance and standing waves. In case we exclusively aimed to study transpersonal experiences and "wave superimposition," excluding proximity reactance, we should have utilized two rooms separating paired and individual conditions. Moreover, neither participant would have been aware of the presence of the other. If knowledge of the other person is removed resonance or standing wave and wave superimposition could have been tested. Although we have no evidence that wave superimposition may have occurred, we cannot exclude the possibility. As a consequence, in addition to higher arousal resulting from social facilitation and the involvement of ToM activation, superimposition of electromagnetic waves may be involved.As it seems that practicing MM together may activate ToM it seems useful that for instance MM therapists could consider practicing MM along with the client or offer mindfulness groups. However, up until now no studies have been performed concerning the effects of practicing MM on brain networks activated by ToM or on coherent brain activity of MM practitioners. Notably, one study in transcendental meditation (TM) has focused on the influence of social interaction on coherent brain activity, comparing EEG coherence during practicing TM alone or in pairs (Newandee & Reisman, 1996). During group TM, a significant increase in intrasubject alpha coherence was observed compared to individual meditation sessions. The higher alpha activity in each subject in the group meditation session suggests that there is a shared mental process of two participants meditating together. Although TM is a very distinct practice from MM, it might be useful to consider studying intrasubject as well as inter subject EEG coherence in individual and paired MM in future studies.

Unfortunately, we have no data on behavioral or subjective effects. It would be interesting to include behavioral measures and subjective reports in future studies. At this point we can only speculate about clinical relevance of our findings. Mere changes in EEG are not necessarily related to changes in behaviour, cognition or subjective experiences (Engelbregt et al., 2016). However, it is interesting that alpha and theta activity increases while practicing together. Specifically, when taking into account that participants were inexperienced meditators only receiving a two-minute introduction and practicing MM for only three minutes.

There are some limitations of the present study. As our sample consisted of educated women in the age range of 18-24 years, the generalizability of the findings is limited. Tasks of this study had a brief duration of only five minutes. Pairs of subjects were tested, divided by a screen, in the same room. Because they closed their eyes during task performance and wore headphones with instructions, there was no physical interaction between participants. This setup was useful in order to keep subjects blind to others' physical appearance and yet give individuals a sense of intersubjective connection while controlling for other aspects of social interaction. However, the data can hardly be used to generalize to everyday social situations.

In conclusion, we found changes in frontal alpha and theta activity in participants' EEG during a short, easy to understand mindfulness task while practicing together as a pair while participants were physically separated from their research partner. Although results of the current study are promising, much more data need to be collected to draw firmer conclusions. Future publications should focus on possible theories about the mechanisms underlying the phenomena discussed here.

Conflict of Interest Statement

All authors declare that they had no conflicts of interest. There was no specific funding for this study neither did any of the authors receive any grants or honoraria with relation to this study.

Ethics Statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The study was approved by the Scientific and Ethical Review Committee at the Faculty of Psychology and Education (VCWE) at the VU University of Amsterdam. Date: 07 Nov 2016, File: VCWE-2016-199. Informed consent was obtained from all individual participants included in the study.

References

Amihai, I., & Kozhevnikov, M. (2014). Arousal vs. relaxation: A comparison of the neurophysiological and cognitive correlates of Vajrayana and Theravada meditative practices. *PLoS One, 9*(7), e102990. https://doi.org/10.1371/journal.pone.0102990

Asada, H., Fukuda, Y., Tsunoda, S., Yamaguchi, M., & Tonoike, M. (1999). Frontal midline theta rhythms reflect alternative activation of prefrontal cortex and anterior cingulate cortex in humans. *Neuroscience Letters, 274*(1), 29–32. https://doi.org/10.1016/S0304-3940(99)00679-5

Baron-Cohen, S. (1997). *Mindblindness: An essay on autism and theory of mind*. MIT Press.

Baron, R. S. (1986). Distraction-conflict theory: Progress and problems. *Advances in Experimental Social Psychology, 19*, 1–40. https://doi.org/10.1016/S0065-2601(08)60211-7

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497. https://doi.org/10.1037/0033-2909.117.3.497

Berkovich-Ohana, A., Glicksohn, J., & Goldstein, A. (2012). Mindfulness-induced changes in gamma band activity—implications for the default mode network, self-reference and attention. *Clinical Neurophysiology, 123*(4), 700–710. https://doi.org/10.1016/j.clinph.2011.07.048

Bernstein, D. A., & Borkovec, T. D. (1973). *Progressive relaxation training: A manual for the helping professions*. Reseach Press.

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin, 132*(2), 180–211. https://doi.org/10.1037/0033-2909.132.2.180

Castellanos, F. X., Di Martino, A., Craddock, R. C., Mehta, A. D., & Milham, M. P. (2013). Clinical applications of the functional connectome. *Neuroimage, 80*, 527–540. https://doi.org/10.1016/j.neuroimage.2013.04.083

Cebolla i Martí, A. J., Demarzo, M., Martins, P., Soler, J., & García Campayo, J. (2017). Unwanted effects: Is there a negative side of meditation? A multicentre survey. *PLoS One, 12*(9), e0183137. https://doi.org/10.1371/journal.pone.0183137

Chiesa, A., & Serretti, A. (2010). A systematic review of neurobiological and clinical features of mindfulness meditations. *Psychological Medicine, 40*(8), 1239–1252. https://doi.org/10.1017/S0033291709991747

Chow, T., Javan, T., Ros, T., & Frewen, P. (2016). EEG dynamics of mindfulness meditation versus alpha neurofeedback: A sham-controlled study. *Mindfulness, 8*(3), 572–584. https://doi.org/10.1007/s12671-016-0631-8

Cottrell, N. B., Wack, D. L., Sekerak, G. J., & Rittle, R. H. (1968). Social facilitation of dominant responses by the presence of an audience and the mere presence of others. *Journal of Personality and Social Psychology, 9*(3), 245–250. https://doi.org/10.1037/h0025902

Creswell, J. D., Pacilio, L. E., Lindsay, E. K., & Brown, K. W. (2014). Brief mindfulness meditation training alters psychological and neuroendocrine responses to social evaluative stress. *Psychoneuroendocrinology, 44*, 1–12. https://doi.org/10.1016/j.psyneuen.2014.02.007

Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences, 19*(9), 515–523. https://doi.org/10.1016/j.tics.2015.07.001

Decety, J., & Sommerville, J. A. (2003). Shared representations between self and other: A social cognitive neuroscience view. *Trends in Cognitive Sciences, 7*(12), 527–533. https://doi.org/10.1016/j.tics.2003.10.004

Dobkin, P. L., Irving, J. A., & Amar, S. (2012). For whom may participation in a mindfulness-based stress reduction program be contraindicated? *Mindfulness, 3*(1), 44–50. https://doi.org/10.1007/s12671-011-0079-9

Engelbregt, H. J., Keeser, D., van Eijk, L., Suiker, E. M., Eichhorn, D., Karch, S., Deijen, J. B., & Pogarell, O. (2016). Short and long-term effects of sham-controlled prefrontal EEG-neurofeedback training in healthy subjects. *Clinical Neurophysiology, 127*(4), 1931–1937. https://doi.org/10.1016/j.clinph.2016.01.004

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Grof, S. (2016). *Realms of the human unconscious: Observations from LSD research*: Souvenir Press.

Hilton, L., Maher, A. R., Colaiaco, B., Apaydin, E., Sorbero, M. E., Booth, M., Shanman, R. M., & Hempel, S. (2017). Meditation for posttraumatic stress: Systematic review and meta-analysis. *Psychological Trauma, 9*(4), 453–460. https://doi.org/10.1037/tra0000180

Ho, R. T. H., Wan, A. H. Y., Chan, J. S. M., Ng, S. M., Chung, K. F., & Chan, C. L. W. (2017). Study protocol on comparative effectiveness of mindfulness meditation and qigong on psychophysiological outcomes for patients with colorectal cancer: A randomized controlled trial. *BMC Complementary and Alternative Medicine, 17*(1), 390. https://doi.org/10.1186/s12906-017-1898-6

Jaspers, H. H. (1958). The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology, 10*, 371–375. https://doi.org/10.1016/0013-4694(58)90051-8

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

Kerr, C. E., Jones, S. R., Wan, Q., Pritchett, D. L., Wasserman, R. H., Wexler, A., Villanueva, J. J., Shaw, J. R., Lazar, S. W., Kaptchuk, T. J., Litenberg, R., Hämäläinen, M. S., & Moore, C. I. (2011). Effects of mindfulness meditation training on anticipatory alpha modulation in primary somatosensory cortex. *Brain Research Bulletin, 85*(3–4), 96–103. https://doi.org/10.1016/j.brainresbull.2011.03.026

Lagopoulos, J., Xu, J., Rasmussen, I., Vik, A., Malhi, G. S., Eliassen, C. F., Arntsen, I. E., Saether, J. G., Hollup, S., Holen, A., Davanger, S., & Ellingsen, Ø. (2009). Increased theta and alpha EEG activity during nondirective meditation. *Journal of Alternative and Complementary Medicine, 15*(11), 1187–1192. https://doi.org/10.1089/acm.2009.0113

Lehmann, D., Faber, P. L., Tei, S., Pascual-Marqui, R. D., Milz, P., & Kochi, K. (2012). Reduced functional connectivity between cortical sources in five meditation traditions detected with lagged coherence using EEG tomography. *Neuroimage, 60*(2), 1574–1586. https://doi.org/10.1016/j.neuroimage.2012.01.042

Lomas, T., Cartwright, T., Edginton, T., & Ridge, D. (2015). A qualitative analysis of experiential challenges associated with meditation practice. *Mindfulness, 6*(4), 848–860. https://doi.org/10.1007/s12671-014-0329-8

Lomas, T., Edginton, T., Cartwright, T., & Ridge, D. (2014). Men developing emotional intelligence through meditation? Integrating narrative, cognitive and electroencephalography (EEG) evidence. *Psychology of Men & Masculinity, 15*(2), 213–224. https://doi.org/10.1037/a0032191

Lomas, T., Medina, J. C., Ivtzan, I., Rupprecht, S., & Eiroa-Orosa, F. J. (2018). A systematic review of the impact of mindfulness on the well-being of healthcare professionals. *Journal of Clinical Psychology, 74*(3), 319–355. https://doi.org/10.1002/jclp.22515

Lopez, S., Gross, A., Yang, S., Golmohammadi, M., Obeid, I., & Picone, J. (2016). *An analysis of two common reference points for EEGs*. Paper presented at the 2016 IEEE Signal Processing in Medicine and Biology Symposium (SPMB). https://doi.org/10.1109/SPMB.2016.7846854

Macleod, J. W., Lawrence, M. A., McConnell, M. M., Eskes, G. A., Klein, R. M., & Shore, D. I. (2010). Appraising the ANT: Psychometric and theoretical considerations of the Attention Network Test. *Neuropsychology, 24*(5), 637–651. https://doi.org/10.1037/a0019803

Mantzios, M., & Giannou, K. (2014). Group vs. single mindfulness meditation: Exploring avoidance, impulsivity, and weight management in two separate mindfulness meditation settings.

Applied Psychology: Health and Well-Being, 6(2), 173–191. https://doi.org/10.1111/aphw.12023

Matiz, A., Fabbro, F., & Crescentini, C. (2017). Single vs. Group mindfulness meditation: Effects on personality, religiousness/spirituality, and mindfulness skills. *Mindfulness, 9*(4), 1236–1244. https://doi.org/10.1007/s12671-017-0865-0

McLeod, S. (2011). McLeod, S. A. (2011, October 24). *Social facilitation*. Simply Psychology. www.simplypsychology.org/Social-Facilitation.html

Meijer, D. K. (2014). The extended brain: Cyclic information flow in a quantum physical realm. *NeuroQuantology, 12*(2), 180–200. https://doi.org/10.14704/nq.2014.12.2.754

Minda, J. P., Cho, J., Nielsen, E., & Zhang, M. (2019). Mindfulness and legal practice: A preliminary study of the effects of mindfulness meditation and stress reduction in lawyers. *PsyArXiv Preprints*. https://doi.org/10.31234/osf.io/6zs5g

Newandee, D. A., & Reisman, S. S. (1996). *Measurement of the electroencephalogram (EEG) coherence in group meditation*. Paper presented at the Proceedings of the IEEE 22nd Annual Northeast Bioengineering Conference. https://doi.org/10.1109/NEBC.1996.503234

Pascual-Marqui, R. D. (2002). Standardized low-resolution brain electromagnetic tomography (sLORETA): technical details. *Methods and Findings in Experimental & Clinical Pharmacology, 24* (Suppl D), 5–12. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12575463

Schuman, M. (1980). The psychophysiological model of meditation and altered states of consciousness: A critical review. In J. M. Davidson & Richard J. Davidson (Eds.), *The Psychobiology of Consciousness* (pp. 333–378): Springer. https://doi.org/10.1007/978-1-4684-3456-9_13

Schurz, M., Radua, J., Aichhorn, M., Richlan, F., & Perner, J. (2014). Fractionating theory of mind: A meta-analysis of functional brain imaging studies. *Neuroscience & Biobehavioral Reviews, 42*, 9–34. https://doi.org/10.1016/j.neubiorev.2014.01.009

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

Shapiro, D., & Walsh, R. (1984). *Meditation: Classic and contemporary approaches*. Aldine.

Shapiro Jr, D. H. (1992). Adverse effects of meditation: A preliminary investigation of long-term meditators. *International Journal of Psychosomatics, 39*(1–4), 62–67.

Sona-systems Ltd. (1997–2019). Sona-systems Ltd. Author. Retrieved from https://www.sona-systems.com

Stiny-Coops, N. (2008). Drie Minuten Ademruimte. Retrieved from https://www.in-balans-met-onrust.nl/2008/11/de-3-minuten-ademruimte-mindfulness.html#wat

Takahashi, T., Murata, T., Hamada, T., Omori, M., Kosaka, H., Kikuchi, M., Yoshida, H., & Wada, Y. (2005). Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. *International Journal of Psychophysiology, 55*(2), 199–207. https://doi.org/10.1016/j.ijpsycho.2004.07.004

Tang, Y. Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., Yu, Q., Sui, D., Rothbart, M. K., Fan, M., & Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences USA, 104*(43), 17152–17156. https://doi.org/10.1073/pnas.0707678104

Thatcher, R. W. (2008). Normative EEG databases and EEG biofeedback. *Journal of Neurotherapy, 2*(4), 8–39. https://doi.org/10.1300/J184v02n04_02

Tsai, J.-F., Jou, S.-H., Cho, W., & Lin, C.-M. (2013). Electroencephalography when meditation advances: A case-based time-series analysis. *Cognitive Processing, 14*(4), 371–376. https://doi.org/10.1007/s10339-013-0563-3

Van Dam, N. T., van Vugt, M. K., Vago, D. R., Schmalzl, L., Saron, C. D., Olendzki, A., Meisssner, T., Lazar, S. W., Kerr, C. E., Gorchov, J., Kieran, C. R. F., Field, B. A., Britton, W. B., Brefczynski-Lewis, J. A., & Meyer, D. E. (2018). Mind the hype: A critical evaluation and prescriptive agenda for research on mindfulness and meditation. *Perspectives on Psychological Science, 13*(1), 36–61. https://doi.org/10.1177/1745691617709589

Van Gordon, W., Shonin, E., & Garcia-Campayo, J. (2017). *Are there adverse effects associated with mindfulness?* SAGE. https://doi.org/10.1177/0004867417716309

Zajonc, R. B., & Sales, S. M. (1966). Social facilitation of dominant and subordinate responses. *Journal of Experimental Social Psychology, 2*(2), 160–168. https://doi.org/10.1016/0022-1031(66)90077-1

Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness & Cognition, 19*(2), 597–605. https://doi.org/10.1016/j.concog.2010.03.014

Zieff, G. (2017). Ancient roots—modern applications: Mindfulness as a novel intervention for cardiovascular disease. *Medical Hypotheses, 108*, 57–62. https://doi.org/10.1016/j.mehy.2017.08.001

Corresponding Author

Jan Berend Deijen, PhD, Section Clinical Neuropsychology, Vrije Universiteit, Amsterdam, The Netherlands.
E-mail: j.b.deijen@vu.nl

About the Authors

Hessel Engelbregt, PhD Student, is founder of Hersencentrum, a multicenter and multi specialism mental health institute in the Netherlands where he now serves as chairman of the umbrella organization's board of directors. In addition, he works part-time as a licensed psychotherapist and as Teamleader Junior Researchers at 'Mental Health Care' (GGZ; ggz.nl). Currently he is finalizing his PhD program at Ludwig Maximillians University Munich under supervision of Prof. Dr. med. Oliver Pogarell. The PhD study mainly focuses on non-invasive brain stimulation. In the lab of Research Director Ass. Prof. Jan Berend Deijen at GGZ and Vrije Universiteit, Hessel's present research is focused on inter-subject EEG coherence, the effects of autonomous sensory meridian response (ASMR) and binaural beats on brain activity.

Hugo Alderse Baas, MA, studied Clinical Neuropsychology at the Faculty of Behavioural- and Movement Sciences of the Vrije Universiteit in Amsterdam. In addition to his master thesis on EEG Coherence in Mindfulness Meditation he completed a second master thesis on determining the necessary cognitive functions for talent identification in professional (pre-) adolescent soccer players. After his graduation in 2017 he has been working at Centrum Indicatiestelling Zorg (Center Indication setting Care) as 'assessor care indication' and since 2019 he is working as ambulatory care worker at Stichting Zorgeloos Ambulant, a mental health care organization in Amsterdam.

Sietske de Grauw, MA, studied Clinical Neuropsychology at the Faculty of Behavioural- and Movement Sciences of the Vrije Universiteit in Amsterdam. Her master thesis concerned the effects of meditation on EEG coherence in healthy adults. After her graduation in 2018 she has been working as a psychologist at Prodeba, an institute for treatment of developmental disorders such as ADHD, autism and anxiety disorders in children and young adults. Thereafter she has been working at Laurens, an institute for elderly care and since 2021 she is working as a psychologist at Novicare, a center for treatment and guidance of physical and mental health problems in elderly and people with intellectual disability.

Jan Berend Deijen, PhD, is Associate Professor at the Section Clinical Neuropsychology of the Faculty of Behavioural- and Movement Sciences of the Vrije Universiteit, Amsterdam. His past research include the cognitive effects of nutrients, neuropsychological markers of Parkinson's disease, and the relationship of growth hormone (GH) and insulin-like growth factor 1 (IGF-1) with (age-related decline in) cognitive functions. For the pharmaceutical industry he studied the cognitive effects of antidepressants, contraceptives and hypnotics, and for the Dutch government the psychological implications of aeroplane noise and the introduction of the Euro in The Netherlands. After his retirement in November 2018 he continued working for the Vrije Universiteit (hospitality) and started to work at Hersencentrum Mental Health Institute Amsterdam. His present research is focused on the effects of mindfulness, breathwork, autonomous sensory meridian response (ASMR) and binaural beats on mood, cognitive functions, brain activity and inter-subject EEG coherence.

About the Journal

The *International Journal of Transpersonal Studies* is a Scopus listed peer-reviewed academic journal, and the largest and most accessible scholarly periodical in the transpersonal field. IJTS has been in print since 1981, is published by Floraglades Foundation, sponsored in part by Attention Strategies, and serves as the official publication of the International Transpersonal Association. The journal is available online at www.transpersonalstudies.org, and in print through www.lulu.com (search for IJTS).