TEMPORAL COGNITION CHANGES FOLLOWING MINDFULNESS, BUT NOT TRANSCENDENTAL MEDITATION PRACTICE

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Abstract

According to the cognitive-timer model, time estimation is dependent on the interplay between arousal level and attention. This anticipates that higher attention and lower arousal, two features of meditation, will result in a longer time production (P). We tested this hypothesis by using a time production task in two forms of meditation: Mindfulness Meditation (MM, n = 36) and Transcendental Meditation (TM, n = 10), with suitable age-matched controls (n = 12 and n = 9, respectively). The MM group was comprised of three groups (n = 12 each) with varying expertise level, to enable studying a meditation proficiency effect. We tested trait and state effects by using a pre – post meditation design. All three MM groups exhibited longer P compared to their control, as predicted. This was found to be a trait effect, as condition or MM expertise did not affect the results. No significant changes in P were found following prolonged TM practice.

Temporal cognition is subjectively reported to be altered to varying degrees during the transcendent state (Glicksohn, 1993; Stace, 1960). A plausible explanation for this phenomenon is given by the cognitive-timer model (Treisman, 1984). According to this model, time estimation is dependent on the interplay between arousal level and attention, two elements which have been shown to be affected by meditation (Pagano & Warrenburg, 1983; Schuman, 1980).

A direct implication of this, suggested by Glicksohn (2001), is that within a time production paradigm, the more focused internally is one's attention (as is during meditation), the slower the rate of functioning of the cognitive timer, coupled with larger subjective time units (S). Time will therefore seem long in passing, as best assessed using the method of time production - with the expectation for longer productions.

Meditation is grossly divided into two forms, as initially proposed by Goleman (1988), and lately elaborated by Lutz et al. (Lutz, Slagter, Dunne & Davidson, 2008): (a) Focused Attention (FA) - learned control over the focus of one's attention by using a stable object, such as a mantra, an image or counting the breath, with the goal of quieting the mind (examples include Raja Yoga, Breathing Meditation and Transcendental Meditation (TM)), and (b) Open Monitoring (OM) – maximizing the breadth and clarity of maintained attention in order to bring higher momentary awareness to internal processes (for example, Zen and Mindfulness Meditation (MM)). The different meditation forms show neurophysiological differences (Dunn, Hartigan, & Mikulas, 1999; Travis & Shear, 2010). Regular meditation practice can produce distinct short term *state* changes, as well as lasting, long term, *trait* changes, that persist irrespective of the meditation activity. Recent studies have emphasized the importance of studying meditation states and traits (Cahn & Polich, 2006; Raffone & Srinivasan, 2010).

Both meditation forms are hypothesized to alter time perception. TM practice, a form of FA practice, emphasizes absence of effort, and when transcendental awareness is achieved, one of its hypothesized characteristics is the loss of time (Raffone & Srinivasan, 2010; Travis, Arenander, & DuBois, 2004; Travis & Pearson, 2000). Similarly, a central feature of the MM state is bringing awareness to current experience, bringing back the wondering mind from the future and the past to the present, fostering a heightened awareness of being in the 'here and now' (Goleman, 1988; Dalai Lama, 1991; Hart, 1987; Teasdale, Segal, & Williams, 1995).

Here we used time production before and after meditation to study trait and state changes in time perception following the two forms of meditation practice. Another question dealt with in this report is the question of meditation expertise – does time perception change in relation to accumulative meditation proficiency?

Methods

Participants and Design

Participants comprised 36 Mindfulness Meditation (MM) practitioners, 10 Transcendental Meditation (TM) practitioners and age-matched healthy controls who had no prior meditation experience, but who declared an interest in meditation in a preceding written interview (interest > 5 on a 0-10 scale). The MM and TM practitioners were recruited via word of mouth in local organizations. The MM practitioners were divided into three groups (n = 12 each) with varying degree of expertise, on the basis of accumulated hours spent in formal meditation during retreats and daily practice (mean ± SD): Short-term (ST, 894 ± 450 h), Intermediate-term (IT, 2570 ± 471 h,), and Long-term practitioners (LT, 7556 ± 502 h). The three MM groups (mean ages: 41.6 ± 13.3, 37.9 ± 10.4, 45.6 ± 10.6, respectively) were age-matched with a control group (n = 12, mean age: 41 ± 12.5). The TM group comprised long-term practitioners (mean ± SD: 16310 ± 11970 h), which were age-matched to 9 controls (CTM) (mean ages: 58.6 ± 6.9 and 51.1 ± 11.6, respectively).

All participants were right handed and healthy, and were tested at least 3 h after their last meditation session, to control for immediate effects and enable studying long-term, trait effects of practice. The research was approved by the institutional ethical committee, and informed consent was obtained from each participant.

The time-production (TP) task was completed twice, pre and post a 15 min meditation session (control participants were given the instruction to “relax as best as you can without falling asleep”).

Time production (TP) task

For an approximate length of 2-3 minutes, the participants were requested by recorded instructions to produce specified target durations by pressing a finger button when they estimated that the time which passed from the 'beep' sound equaled the specified requested duration. Four time intervals were used: 4, 8, 16 and 32 sec, each interval twice, with random order of presentation (Glicksohn, Berkovich-Ohana, Balaban-Dotan, Goldstein, & Donchin, 2009). Before the task, a practice of two time intervals (4 and 8 sec) was given. The task was performed with closed eyes to reduce ocular artifacts in the EEG. The participants were not supervised concerning the time estimation strategy during the task itself (internal counting, or other), and were questioned afterwards concerning the employed strategy. Produced (P) and target durations (T) were log-transformed (to base 2), with required durations rendering thereby a linear scale ranging between 2 and 5, with a midpoint value of 3.5; P was then regressed on T.

Results

Subjective reports

During the TP task, the percentages of participants who reported mental counting were 100% for the control groups as well as for ST-MM and IT-MM groups, and above 85% for the LT-MM and TM (the rest of the LT-MM and TM reported 'unverbal sensing' the passage of time rather than counting).

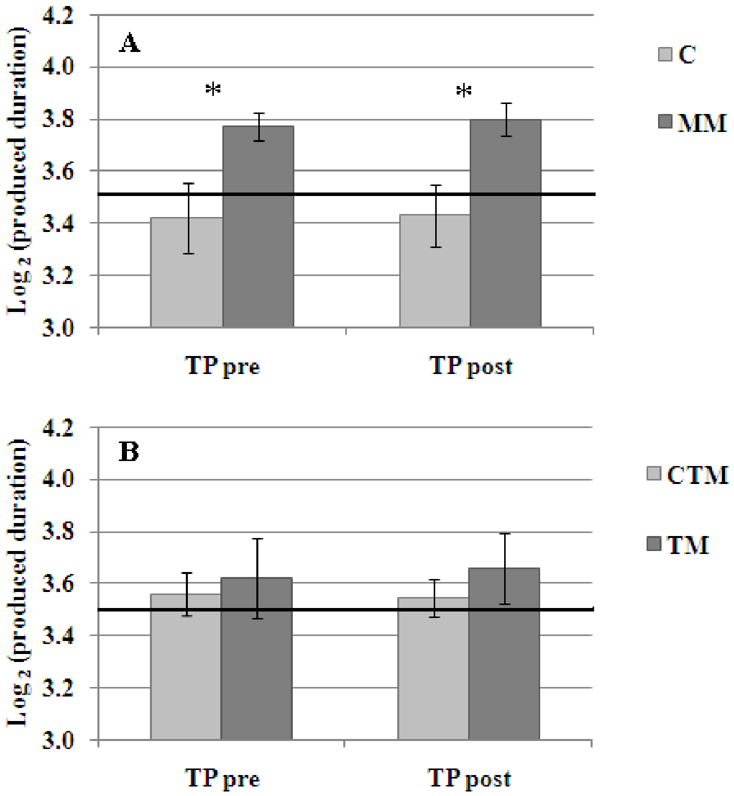

Figure 1: Log (produced durations) for MM (A) and TM (B) vs. their control groups, in the TP task pre and post meditation. * $p < .005$.

Time production

A two-way analysis of variance (ANOVA) was performed on the log transformed produced (*P*) durations. The first was designed to answer the question: Does MM practice alter temporal perception? This ANOVA had one Grouping factor (MM and C), and repeated measures on Condition (Pre and Post), adopting the Greenhouse-Geisser *p*-value for each and every effect. We found a main effect for Group [$F(1,45) = 9.59$, $MSE = 0.23$, $p < .005$], with the MM group exhibiting significantly longer *P* compared to controls (Figure 1A). There was no Condition effect, or interaction. This result suggests a trait difference between the MM and C groups in temporal cognition. When conducting the same ANOVA for the TM and CTM groups there were no significant effects (Figure 1B). This indicates that temporal cognition is significantly altered following MM practice, as hypothesized, but not following long-term TM practice.

A second ANOVA, designed to test expertise level differences between the three MM groups, had one Grouping factor (ST-MM, IT-MM and LT-MM), and repeated measures on Condition, as before. This did not yield any significant effects, indicating that MM induces temporal cognition changes from the early stages of practice, not significantly affected by proceeding practice.

P in both TP pre and post did not correlate significantly with age over all participants, nor with MM expertise.

Discussion

As the required durations rendered a linear scale ranging between 2 and 5, with a midpoint value of 3.5, values below 3.5 indicate shorter produced duration compared to the objective passing time, and vice versa. It can be clearly seen (Figure 1A) that while the MM groups produced durations above the objective durations (the solid line at $P = 3.5$), the opposite is true for their control group. It can be also seen (Figure 1B) that TM practitioners did not show this effect compared to their controls.

We hypothesized that the subjective time-unit (estimated by the log-transformed produced durations - P) will increase as state and trait effect in meditators. The results indicate that indeed, MM practice alters temporal perception in the direction of longer subjective time-unit. The lack of a condition effect suggests a trait neuroplasticity change in temporal cognition, rather than a state change. This effect was not found in the TM group, in contrast to the hypothesis. One possible explanation for the discrepancy in MM and TM effects on temporal cognition might have stemmed from the age differences, as the TM practitioners were significantly older than the MM practitioners. However, we didn't find any significant correlation between P and age, rendering this explanation as less feasible. Another finding is that increasing MM proficiency did not affect the subjective time units, suggesting that the neuroplasticity in the temporal cognition networks take place in the early stages of MM practice.

Subjective reports on the effects of meditation have included changes in perceptual awareness (Baruss, 2003; Brown, 1977; Carter, Presti, Callistemon, Ungerer, Liu, & Pettigrew, 2005). It was previously hypothesized that these subjective changes in awareness and consequent perception were due to a change in the subjective temporal experience of ‘‘now’’ (Brown, Forte, & Dysart, 1984). This brings to mind the division between 'core consciousness', related to momentary awareness and the core-self, and 'extended consciousness', embedded in memory and the passage of time and related to the narrative-self (Damasio, 1999). The rising question is whether MM practitioners rely stronger, as a trait, on core-consciousness compared to controls?

We suggest that this is the case, based on the following arguments: First, functional magnetic resonance imaging (fMRI) recently revealed that time dilation occurs in conjunction with the activation of several midline structures, such as the anterior cingulate and left precuneus (Van Wassenhove, Wittmann, & Paulus, 2011; Wittmann, Van Wassenhove, Craig, & Paulus, 2010), previously related to core self-referential processing (Northoff & Bermpohl, 2004; Northoff, Heinzel, de Greck, Bermpohl, Dobrowolny, & Panksepp, 2006). Second, both fMRI (Farb, Segal, Mayberg, Bean, McKeon, Fatima, & Anderson, 2007) and EEG (Berkovich-Ohana, Glicksohn, & Goldstein, 2011) studies suggested that brain activity related to narrative self-reference processing is reduced following MM practice. Finally, our own work (Berkovich-Ohana et al., 2011) showed that the produced durations in MM practitioners were negatively correlated with trait frontal gamma activity, related to lower narrative self-reference. Thus, the lower the "narrative-self activity" is, the produced duration (P) increases, indicating stronger momentary experience attributed to the core-consciousness.

This line of thought, relating time dilation with lower narrative self-reference processing, might illuminate the discrepancy reported here between MM and TM. Meditations as found in the Buddhist traditions such as MM focus on momentary experience and the outside world, struggling to eradicate the self, leading to lower narrative self-reference processing and time dilation. In contrast, meditation in the Hindu traditions such as TM use precisely the opposite approach, shutting out the outside and focusing on the Self (Dreyfus & Thompson, 2007; Malach, 2006), thus do not cause time dilation.

To conclude, it is tempting to suggest that the lower narrative self-referential processing induced by MM practice also induces a shift towards momentary core-consciousness, marked by temporal cognition changes in the direction of time dilation. However, this possible intriguing connection and its underlying neurophysiological mechanism require further research.

References

Baruss, I. (2003). *Alterations of consciousness: An empirical analysis for social scientists*. Washington, DC: American Psychological Association.

Berkovich-Ohana, A., Glicksohn, J., & Goldstein, A. (2011). Mindfulness-induced changes in gamma band activity – implications for the default mode network, self-reference and attention. *Clinical Neurophysiology*, in press.

Brown, D. (1977). A model for the levels of concentrative meditation. *International Journal of Clinical and Experimental Hypnosis*, *25*, 236-273.

Brown, D., Forte, M., & Dysart, M. (1984). Visual sensitivity and mindfulness meditation. *Perceptual and Motor Skills*, *58*, 775-784.

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*, *132*, 180-211.

Carter, O. L., Presti, D. E., Callistemon, C., Ungerer, Y., Liu, G. B., & Pettigrew, J. D. (2005). Meditation alters perceptual rivalry in Tibetan Buddhist monks. *Current Biology*, *15*, 412-413.

Dalai Lama, X. I. V. (1991). *Path to Bliss*. Ithaca, Snow Lion.

Damasio, A.R. (1999). *The feeling of what happens: Body and emotion in the making of consciousness*. New York: Harcourt Brace.

Dreyfus, G., & Thompson, E. (2007). Asian perspectives: Indian theories of mind. *E. Thompson, P. D. Zelazo & M. Moscovitch (Eds.), The Cambridge handbook of consciousness* (pp. 89–114). Cambridge: Cambridge University Press.

Dunn, B. R., Hartigan, J. A., & Mikulas, W. L. (1999). Concentration and mindfulness meditations: Unique forms of consciousness? *Applied Psychophysiology and Biofeedback*, *24*, 147-165.

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

Glicksohn, J. (1993). Altered sensory environments, altered states of consciousness and altered-state cognition. *The Journal of Mind and Behavior*, *14*, 1-12.

Glicksohn, J. (2001). Temporal cognition and the phenomenology of time: A multiplicative function for apparent duration. *Consciousness and Cognition*, *10*, 1-25.

Glicksohn, J., Berkovich-Ohana, A., Balaban-Dotan, T., Goldstein, A., & Donchin, O. (2009). Time production and EEG alpha revisited. *NeuroQuantology*, *7*, 138-151.

Goleman, D. (1988). *The meditative mind–the varieties of meditative experience*. New York: GP Putnam & Sons.

Hart, W. (1987). *The art of living: Vipassana meditation as taught by SN Goenka*. San Francisco, CA: Harper & Row.

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Cognitive-emotional interactions: Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences*, *12*, 163-169.

Malach, R. (2006). Perception without a Perceiver: In Conversation with Zoran Josipovic. *Journal of Consciousness Studies*, *13*, 57-66.

Northoff, G., & Bermpohl, F. (2004). Cortical midline structures and the self. *Trends in Cognitive Sciences*, *8*, 102-107.

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain--a meta-analysis of imaging studies on the self. *NeuroImage, 31*, 440-457.

Pagano, R. R., & Warrenburg, S. (1983). Meditation: In search of a unique effect. In R. J. Davidson, G. E. Schwartz & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (Vol. 3, pp. 153-210). New York: Plenum.

Raffone, A., & Srinivasan, N. (2010). The exploration of meditation in the neuroscience of attention and consciousness. *Cognitive Processing*, *11*, 1-7.

Schuman, M. (1980). The psychophysiological model of meditation and altered states of consciousness: A critical review. In J. M. Davidson & R. J. Davidson (Eds.), *The psychobiology of consciousness* (pp. 333-378). New York: Plenum Press.

Stace, W. T. (1960). *Mysticism and philosophy*. Los Angeles: Jeremy P. Tarcher.

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

Travis, F., Arenander, A., & DuBois, D. (2004). Psychological and physiological characteristics of a proposed object-referral/self-referral continuum of self-awareness. *Consciousness and Cognition*, *13*, 401-420.

Travis, F., & Pearson, C. (2000). Pure consciousness: distinct phenomenological and physiological correlates of "consciousness itself." *International Journal of Neuroscience*, *100*, 77-89.

Travis, F., & Shear, J. (2010). Focused attention, open monitoring and automatic self-transcending: Categories to organize meditations from Vedic, Buddhist and Chinese traditions. *Consciousness and Cognition*, *19*, 1110-1118

Treisman, M. (1984). Temporal rhythms and cerebral rhythms. In J. Gibbon & L. Allan (Eds.), *Timing and time perception. Annals of the New York Academy of Sciences* (Vol. 423, pp. 542-565). New York: The New York Academy of Sciences.

Van Wassenhove, V., Wittmann, M., & Paulus, M. P. (2011). Frontiers: Psychological and neural mechanisms of subjective time dilation. *Frontiers in Neuroscience, 5*, 56.

Wittmann, M., Virginie van Wassenhove, A. D., Craig, A. D., & Paulus, M. P. (2010). The neural substrates of subjective time dilation. *Frontiers in Human Neuroscience, 4*, 2.