Changes in in the temporal width of the present moment after meditation
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Changes in subjective time and self but not the temporal width of the present moment after meditation

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Abstract

This study examines the effects of meditative states in very experienced meditators on the present moment awareness, subjective time and the awareness of the self while exploring its relationship with meditation-induced heart-rate variability (HRV) and respiratory changes. Following a within-subject design, a sample of experienced mindfulness-meditators (n = 22) accomplished a metronome task, as an operationalization of the present moment awareness, before and after 20-minutes meditation session (experimental condition) and a 20-minutes reading session (control condition). Electrocardiogram (ECG) and respiratory activity were recorded during both sessions and compared to a 5-minutes resting-state. Self-report scales related to subjective time (i.e., passage of time, time intensity) and to the awareness of the self (i.e., body boundaries, body-self intensity) were filled in after both conditions. Concerning the metronome task no significant differences between conditions became apparent. Participants perceived their body boundaries as less salient during meditation than while reading the story; they also felt time as passing more quickly and they directed less attention to time during meditation. Depending on the parameter, there was a mixed pattern of more sympathetic and parasympathetic activity during meditation: concerning physiological indices, breathing intervals were prolonged during meditation; heart-rate variability parameters higher α-1 and lower α-2 levels in the meditation condition; levels of ApEn and SampEn, measures of HRV complexity, were lower during meditation. To sum up, meditation led to several changes in physiological parameters and subjective experience, i.e. less pronounced body boundaries and less awareness of time but no changes in the accentuation of metronome beats.

Aims

The purpose of the present study is to test this issue by assessing the influences of meditative states and related autonomic physiological changes (HRV and breathing rate) on the present moment experience, subjective time, and awareness of the body self in meditators with a long history of meditation experience. To this aim, 22 experienced mindfulness meditators, who meditated for 20 minutes and used their own meditation techniques, were assessed. Using a within-subject design, the performance on a metronome task was compared before and after two different conditions (i.e., 20-minutes meditation session vs. 20-minutes reading a novel). Moreover, meditation depths, individual's self-reported perception of the own body (e.g., intensity and salience of body boundaries), and experienced time during both conditions was assessed. We hypothesized that:

1. Mindfulness-meditation states yield to changes in autonomic activity (HRV)
2. Mindfulness-meditation states yield to alterations on the width of the present moment, as assessed with the metronome task.
3. Meditation induced-changes in autonomic activity (HRV) relate to the alterations on the width of the present moment.
4. Subjective time and perceived salience of body boundaries differ between conditions, i.e. are less pronounced.
5. Meditation induced-changes in autonomic activity (HRV) relate to the alterations on the width of the present moment.

Materials and methods

Participants

The study included 22 long-term meditation practitioners (12 females, 10 males; mean age: 47 years; S.D. = 12 years; age-range: 26-67 years). Only meditators practicing meditation techniques stressing awareness of the present moment were recruited (secularized forms of mindfulness meditation: 2; Vipassana meditation: 8; Zen: 8; Tibetan Buddhism: 4). They were selected based on the criterion of at least five years of regular meditation practice and at least two meditation sessions per week in the last two month (years of meditation experience: mean = 19.15; S.D. = 14.83; meditation sessions per week in the last two months: mean = 3.95; S.D. = 2.08). The amount of formal meditation training was calculated by adding the number of hours of daily sitting-meditation practice and the number of hours of sitting meditation spent in meditative retreats (hours of formal meditation training: mean = 2294.22; S.D. = 3213.44). Participants were recruited by advertisements in meditation centers and by word of mouth. They were fluent in German and reported having no history of neurological or psychiatric disorders. Individuals received a financial compensation (€25) for taking part in the two study sessions conducted on two consecutive days and lasting about one hour each. The study was approved by the local Ethics Committee of the Institute for Frontier Areas of Psychology and Mental Health (IGPP, Freiburg, Germany). All participants provided written informed consent prior to data collection.

Procedure

The study followed a within-subject design including two assessment-time points. On two consecutive days participants' underwent a meditation session and a relaxed reading session (counterbalanced order across subjects): the experimental condition (20-minutes meditation session) and the control condition (20-minutes reading session). Physiological measures (heart rate, breathing rate) were recorded during each session. Performance in the metronome task assessing present-moment awareness was compared before and after each condition (four measurements). Subjective time and the bodily self were assessed with questionnaires following each session. In the meditation condition (i.e. experimental condition) participants were asked to meditate 20 minutes using their own meditation technique. All participants practiced a sitting meditation while using a cushion or a bench placed on a meditation mat. A timer application (i.e., Bodhi Timer) playing a gong sound was used to signalize the beginning and the end of the meditation session. In the reading condition (i.e. control condition) participants were asked to read, leisurely and in an active way, an excerpt of the German translation of the Dutch novel *The Detour* by Gerbrand Bakker while adopting the same bodily posture as in the meditation session. The reading session lasted 20 minutes.

Instruments

Physiological recording

The electrocardiogram (ECG) was recorded with the eMotion FAROS 360° mobile device (Mega Electronics Ltd., Kuopio, Finland), a three-channel ECG recorder. This device also records breathing activity with an integrated 3-D accelerometer placed on the chest.

Questionnaires and analogue scales

The Meditation Depth Questionnaire (MEDEQ, Piron 2001), the Perceived Body Boundaries Scale (PBBS; Dambrun, 2016), and the Inventory on subjective time, self, and space (STSS; (Pfeifer et al., 2016) were used to assess the subjective experience during meditation.

The metronome task

The metronome task is made up of unaccented isochronous auditory clicks, i.e. beats. Each single beat lasted 19 milliseconds. Sequences of beats comprised the following frequencies: 2, 1.33, 1, 0.5, and 0.33 s inter-stimulus intervals (ISI) and lasted 15 s. Participants were asked to let an accentuated rhythmic pattern emerge spontaneously (e.g., 1-2, 1-2, or 1-2-3, 1-2-3, etc.) and to report the number of beats the rhythmic pattern contained using a computer keyboard. They were asked to respond as soon as the rhythmic pattern emerged. The temporal extent of the rhythmic pattern was calculated from the number of integrated beats into one rhythmic group. This dependent variable was labeled as interval of 'temporal integration' (TI). TI corresponds to the span of the integrated beats from onset to onset into one temporal unit.

Results

Descriptive statistics

Descriptive statistics for the study group (n = 22) are summarized in Table 1.

Table 1: Descriptive statistics of the study group (n = 22).

Variable	Participants (n = 22)
Age (mean ± SD)	47.18 ± 12.45
Gender (female (%))	12 (55)
Educational level:	
High school degree (n (%))	7 (31.8)
University degree (n (%))	15 (68.2)
Meditation experience:	
Lifetime in years (mean ± SD)	19.16 ± 14.83
Lifetime in hours (mean ± SD)	2994.22 ± 3213.44
In hours per week (mean ± SD)	4 ± 2.08

Between-condition differences in physiological variables

Means, SD, and within-subject differences between conditions calculated with a dependent-sample *t*-test (two-sided) for the physiological variables are presented in Table 2. As expected, no significant differences were found for the baseline (BL) measures (before the session). There was a significant difference between conditions (meditation vs. story) with respect to the mean duration of the breathing period (BR: breathing period [s]; $t(15) = 2.87$, $p = .012$, $d = 0.91$). Participants had longer breathing intervals during the meditation session (M = 4.88; SD = 0.84) than during listening to the story (M = 4.18; SD = 0.69). Further significant differences between conditions were found with respect to alpha 1 (α 1; $t(21) = 2.74$, $p = .012$, $d = 0.60$), alpha 2 (α 2; $t(21) = -2.78$, $p = .011$, $d = 0.72$), approximate entropy (ApEn; $t(21) = -3.27$, $p = .004$, $d = 0.42$), and sample entropy (SampEn; $t(15) = 3.50$, $p = .002$, $d = 0.71$). In the meditation condition participants showed higher α 1 levels (M = 1.35; SD = 0.23) than in the story condition (M = 1.17; SD = 0.35); α 2 levels were lower during meditation (M = 0.27; SD = 0.10) than while reading the story (M = 0.35; SD = 0.12). Participants had lower levels of ApEn and the SampEn during meditation (ApEn: M = 1.22; SD = 0.20; SampEn: M = 1.32; SD = 0.27) than while reading the story (ApEn: M = 1.38; SD = 0.17; SampEn: M = 1.55; SD = 0.29).

Table 2: Descriptive statistics for the physiological variables in the two conditions (n = 22).

Variable	**Meditation condition (n = 22)**	**Story condition (n = 22)**	***p*-values**
BL BR: breathing period [s] (mean ± SD)	4.22 ± 0.64	4.23 ± 0.70	0.974
BL RMSSD (mean ± SD)	29.36 ± 17.74	27.35 ± 13.82	0.415
BL α 1 (mean ± SD)	1.16 ± 0.26	1.18± 0.29	0.707
BL α 2 (mean ± SD)	0.29 ± 0.14	0.33 ± 0.19	0.370
BL ApEn (mean ± SD)	1.12 ± 0.24	1.07 ± 0.17	0.392
BL SampEn (mean ± SD)	1.47 ± 0.28	1.49 ± 0.33	0.779
Session BR: breathing period [s] (mean ± SD)	4.88 ± 0.84	4.18 ± 0.69	**0.012*** [b, FDR]
Session RMSSD (mean ± SD)	27.84 ± 11.88	28.23 ± 14.19	0.881
Session α 1 (mean ± SD)	1.35 ± 0.23	1.17 ± 0.35	**0.012*** [b, FDR]
Session α 2 (mean ± SD)	0.27 ± 0.10	0.35 ± 0.12	**0.011*** [b, FDR]
Session ApEn (mean ± SD)	1.22 ± 0.20	1.38 ± 0.17	**0.004**** [b, FDR]
Session SampEn (mean ± SD)	1.32 ± 0.27	1.55 ± 0.29	**0.002**** [b, FDR]

The variable BL represent the values of the 5-min. baseline (BL) measure: no difference at baseline before the two sessions. The variable Session corresponds to the physiological values during the two condition sessions; Significant coefficients: *p < .05, **p < .01, ***p < .001 marked **in bold**; [FDR]significant after FDR correction; [b] For Cohen's *d* see in text.

Temporal integration of metronome beats

A series of repeated-measures ANOVA with 2 (condition: meditation session vs. reading session) x 2 (time: pre-session vs. post-session) in temporal integration intervals (TI) for each metronome frequency (2, 1.33, 1, 0.5, and 0.33 s. ISI) were performed to test Hypothesis 1 (i.e., Hypothesis 1: Mindfulness-meditation states lead to alterations on the width of the present moment, as assessed with the metronome task, post- vs. pre-session). These analyses revealed neither main effects nor time-by-condition interactions. Across all frequencies, *p*-values corresponding to the main effects 'time' and 'condition' were all larger than .05. *P*-values corresponding to the interaction between 'time' * 'condition' were larger than .05 across frequencies. Descriptive statistics for these analyses are presented in Table 3.

Table 3: Descriptive statistics for the temporal integration (TI) at the different frequencies of the metronome (n = 19).

Variable	Time	Meditation condition	Story condition
TI at 2 s. ISI (mean ± SD)	Pre	3.26 ± 1.66	3.15 ± 1.38
	Post	3.57 ± 1.95	3.05 ± 1.68
TI at 1.33 s. ISI (mean ± SD)	Pre	2.87 ± 1.19	2.94 ± 1.37
	Post	2.48 ± 1.08	2.80 ± 1.16
TI at 1 s. ISI (mean ± SD)	Pre	2.05 ± 0.62	2.57 ± 1.12
	Post	2.26 ± 1.19	2.15 ± 0.83
TI at 0.5 s. ISI (mean ± SD)	Pre	1.63 ± 0.92	1.57 ± 0.93
	Post	1.44 ± 0.83	1.63 ± 0.99
TI at 0.33 s. ISI (mean ± SD)	Pre	1.26 ± 0.83	1.26 ± 0.85
	Post	1.04 ± 0.63	0.88 ± 0.45

Subjective time and body-self boundaries

Means, SD and within-subject differences between conditions (calculated with a dependent sample *t*-test; two-sided) for the PBBS and the STSS state-scales are presented in Table 4.

There was a significant difference between conditions (meditation vs. story) with respect to *body-self boundaries* (BB; $t(21) = -3.30$, $p = .003$, $d = 0.94$) and the sub-scales *passage of time* (POT; $t(21) = 2.68$, $p = .014$, $d = 0.81$) as well as *attention to time* (ATT; $t(21) = -3.32$, $p = .003$, $d = 0.80$) of the STSS scale. Participants perceived their body boundaries as less salient during meditation (M = 1.81; SD = 1.25) than while reading the story (M = 3.27; SD = 1.80). They also felt the time passed more quickly (POT: M = 68.76; SD = 22.56) and directed less attention to time (ATT: M = 22.38; SD = 22.15) during meditation than while reading the story (POT: M = 51.14; SD = 20.85; ATT: M = 43.14; SD = 29.04). None of the other dimensions of the STSS were statistically significant between conditions.

Table 4: Descriptive statistics and independent *t*-test significance in between conditions for the PBBS and the STSS (n = 22).

Variable	Meditation condition	Story condition	*p*-values[a]
Body boundaries (mean ± SD)	1.81 ± 1.25	3.27 ± 1.80	**0.003**** [b; FDR]
Body intensity (mean ± SD)	4.00 ± 1.63	3.90 ± 1.54	0.883
Passage of time (mean ± SD)	68.76 ± 22.56	51.14 ± 20.85	**0.014*** [b; FDR]
Attention to time (mean ± SD)	22.38 ± 22.15	43.14 ± 29.04	**0.003**** [b; FDR]

[a] t-Test if not otherwise indicated: *$p < .05$, **$p < .01$, ***$p < .001$ marked **in bold**; [FDR]significant after FDR correction; [b] For Cohen's *d* see in text.

Correlations between physiological variables, subjective time and body boundaries

Results from the correlations between physiological variables and the subjective time and body boundaries are listed in Table 5. A negative correlation between ApEn and passage of time was found (r = -0.497, p = .022). The SampEn was also negatively correlated with passage of time (r = -0.507, p = .019). These results indicate that individuals having higher levels of ApEn and SampEn estimated time to pass more slowly during the meditation session.

Table 5: Correlations between physiological variables, subjective time and body boundaries (n = 22).

Variable	BR	α 1	α 2	ApEn	SampEn
Body boundaries	-0.297	-0.041	-0.222	0.095	0.080
Body intensity	0.009	0.148	0.105	0.019	0.018
Attention to time	0.154	0.312	-0.402	0.112	0.042
Passage of time	0.297	0.273	-0.029	**-0.497***[b]	**-0.507*** [b]

Significant correlation coefficients: *$p < .05$, **$p < .01$, ***$p < .001$ (two-tailed); b = not significant after α correction.

Correlations between meditation depths, subjective time and body boundaries

Table 6: Correlations between physiological variables, subjective time and body boundaries (n = 22).

Variable	MEDEQ
Body boundaries	-0.384
Body intensity	-0.332
Attention to time	-0.338
Passage of time	0.104

Significant correlation coefficients: *$p < .05$, **$p < .01$, ***$p < .001$ (two-tailed).

Correlations between the scores of the Meditation Depth Questionnaire (MEDEQ) and subjective time and body boundaries are listed in Table 6. Weak to moderate correlation coefficients, which are however not significant (p > 0.05), in the hypothesized direction appear for three variables, which indicates that the deeper meditation were during meditation, the weaker the body boundaries, the less intensive the body feeling, and the less attention to time.

Discussion, Conclusions, and Recommendations

This study explored the effects of meditation in experienced meditators on the present moment awareness, subjective time and bodily self while at the same time assessing the physiological parameters of the heart-rate and respiratory changes. In a within-subject design, we compared a sample of experienced mindfulness-meditators (n = 22) before and after a 20-minutes meditation session (experimental condition) and a 20-minutes reading session (control condition).

Concerning physiological indices, the breathing rate was reduced during meditation as compared to the reading condition, that is, the breathing periods were longer which is indicative of a more relaxed state typically found in meditative states (Linares Gutiérrez et al., 2019). Regarding heart rate, participants had higher α-1 and lower α-2 levels in the meditation condition than while reading the story. While α 1 relates to sympathetic activity, which was increased during meditation, α 2 reflects sympathetic as well as parasympathetic activities, α 2 being reduced during meditation. Furthermore, participants during meditation had lower levels of ApEn and SampEn, a measure of heart-rate variability (HRV) complexity, and related to parasympathetic modulation. How to interpret the latter measures of HRV complexity? A time series containing many repetitive patterns has a relatively smaller ApEn (more predictability); a less predictable (i.e., more complex) process has a larger ApEn (Ahn & Kim, 2019). Regarding this interpretation of the data, meditative states with a smaller ApEn thus has a more predictable, i.e. less complex, HRV. As a comparison, higher entropic, less predictable, states are typically found in individuals under the influence of psychedelics (Carhart-Harris, 2018). Similar to other altered states of consciousness, meditation cannot be conceived in simple, uniform physiological categories (Millière et al, 2018). Meditation thereafter is not a state of uniform passive relaxation, but of concentrated wakefulness which is influenced by the specifics of the meditation technique. Across physiological indices, an increase or decrease in parasympathetic and sympathetic parameters can therefore often be recorded at the same time (Winter et al., 2020; Nesvold et al., 2012). What we show here is that a mix of physiological parameters pertaining to the heart and breathing rate has significantly different characteristics during meditation as compared to control reading session.

Regarding the operationalization of present-moment awareness, the metronome task showed no significant differences between conditions. In a similar pre-post longitudinal study, with less experienced meditators in an inter-subject design with 41 and 43 subjects, respectively, in a meditation and a control condition (passive listening to a recorded story), meditation led to an increase of the duration of integration intervals at the slowest metronome frequency (inter-stimulus interval, ISI = 3 s) (Linares Gutiérrez et al., 2019). Although there was a tendency for an increased integration interval at our slowest metronome frequency (ISI = 2 s) with the n = 22 subjects this difference was not significant. This leads us to suggest that the sample was not large enough. One problem, only partly related to the corona situation with several more or less strict lockdowns, was to find and recruit meditators with the meditation experience we were looking for. In the end, we had to contend ourselves with the number of meditators we were able to recruit. Another possibility for the null finding is that some individuals had difficulties understanding the task and thereafter grouping the metronome beats into meaningful chunks. A future possibility is to present the metronome beats in a passive setup without requiring participants to explicitly decide on auditory groups and to record auditory-evoked potentials in the brain which reflect the automatic accentuation (Brochard et al., 2003).

In the subjective reports of participants on time and the bodily self, their body boundaries were less salient during meditation than while reading the story; they also felt time passing more quickly and they directed less attention to time. Correlational analyses, although with moderately strong correlation coefficients but after α correction not significant, revealed that individuals attaining deeper meditative states during the meditation condition were less aware of the surrounding space and that those individuals having a lower HRV complexity estimated time to pass faster during the meditation session. One qualitative study has so far shown how the awareness of the passage of time is diminished in unison with the experienced self in meditation (Droit-Volet & Dambrun, 2019). Our study is perhaps the first to quantitatively assess subjective time and self across the meditation session itself and probing for these changes in a relatively experienced sample of meditators. This study with very experienced meditators is in accordance with knowledge of other psychological or pharmacological induction types of altered states of consciousness where in peak states time and self are temporarily lost (Wittmann, 2015, 2018). Here we show the same phenomenon quantitatively with the psychological technique of meditation.

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