

Physiological and psychological correlates of attention-related body sensations (tingling and warmth)

BT Tihanyi^{1,2}, F Köteles¹

¹Institute of Health Promotion and Sport Sciences, ELTE Eötvös Loránd University, Budapest, Hungary

²Doctoral School of Psychology, Institute of Health Promotion and Sport Sciences, ELTE Eötvös Loránd University, Budapest, Hungary

Received: December 6, 2016

Accepted: September 7, 2017

Body sensations play an essential role in the subjective evaluation of our physical health, illness, and healing. They are impacted by peripheral somatic and external processes, but they are also heavily modulated by mental processes, e.g., attention, motor control, and emotion. Body sensations, such as tingling, numbness, pulse, and warmth, can emerge due to simply focusing attention on a body part. It is however an open question, if these sensations are connected with actual peripheral changes or happen “only in the mind.” Here, we first tested whether the intensity of such attention-related body sensations is related to autonomic and somatomotor physiological processes and to psychological traits. In this study, attention-related body sensations were not significantly connected to changes in physiology, except warmth sensation, which was linked to decrease in muscle tension. Overall intensity of tingling significantly correlated with body awareness and tendentially with body–mind practice. This strengthened the hypothesis that attention-related body sensations are more the result of top–down functions, and the connection with peripheral processes is weak. Here, we suggested a novel protocol to examine the effect of manipulating attention on body sensations, which together with our results and discussion can inspire future researches.

Keywords: psychophysiology, body attention, body awareness, tingling, body sensation

Introduction

Full understanding of how we perceive our body through the interoceptive system seems problematic, since there is a growing body of evidence demonstrating that various body sensations can be experienced even in the complete absence of obvious physiological changes or external manipulation. Such sensations were reported in various experimental studies, which explored, e.g., placebo treatment (10), sham electrical (26, 41) or vibratory tactile stimulation (38), verbal suggestion (55), and even mere attentional focus on a body part (36). Self-consciousness theory states that introspection intensifies perceived internal states, e.g., body sensations, emotions, and motives, which lead to a more accurate self-perception (15). This latter idea, also called *veridicality* (“*veracity*”) or *perceptual accuracy hypothesis* (24), however, was not supported by empirical findings (54). For example, the perception of body arousal, similar to other forms of perception, is impacted by various biases and top–down influences, e.g., false physiological or verbal feedback (1, 13, 16, 17, 25, 39, 44, 62, 64). In

Corresponding author: Benedek T. Tihanyi, MD

Institute of Health Promotion and Sport Sciences, ELTE Eötvös Loránd University

Bogdánfy u. 10, Budapest 1117, Hungary

Phone: +36 3 0906 9953; Fax: +36 1 381 2182; E-mail: tihanyibenedekt@gmail.com

other words, only the neuronal representation of arousal is experienced consciously, and not arousal *per se* (18). The same holds true for the experience of body processes and symptoms; as they represent the conscious outcome of a complex perception process, they are often not or just weakly connected to elementary sensory events (32, 33, 35, 46–48, 52).

Here, we will examine body sensations, such as tingling, numbness, pulse, and warmth, which emerge during simply focusing attention on a body part (36). We will refer to this phenomenon briefly as attention-related body sensation. Regarding the psychophysiological background of attention-related body sensations, three independent but possibly interacting mechanisms are conceivable. First, there is a constant spontaneous activation of the interoceptive sensory neurons stimulated by basic peripheral physiological fluctuation, or ectopic activation of peripheral, and more importantly, central sensory neurons. This activity is usually filtered out to liberate attentional resources, but attention can let it pop out and reach consciousness (12, 36, 42). Further mental processes were suggested to exert an effect on attentional filtering and thus modulate body sensations, such as expectation (46), motivation (63), decision-making (27), and emotion (56). For example, expectations of given body changes are able to shape low-level (i.e., non-conscious) filtering processes; those components of spontaneous fluctuations (i.e., noise) that are in accordance with the expectation will be further processed and interpreted as actual changes (i.e., signal), whereas contradictory information will be rejected (21, 45, 46, 50, 51). Such top-down modulation can happen within the brain or even at the spinal level (53).

The second possible mechanism of the psychophysiological background of attention-related body sensations is that top-down processes activate somatosensory representations even in the total absence of any bottom-up information, i.e., they can be of purely central origin (10). This is supported by the model of “as if body loop,” a cerebral circuit that starts from the ventromedial prefrontal cortex, activating the secondary and primary somatosensory cortex, insula, and even brain stem nuclei, which results in the central simulation of peripheral events (9).

The third possible mechanism is that body attention impacts the motor coordination and/or affective state, which in turn changes the state of peripheral tissues through the somatomotor and the visceromotor nervous system. It is well known that emotions are strongly connected to body sensations (43) and recently it was also found that motor activation is able to alter (typically inhibit) body sensations (8). It is possible that attentional focus on a body part either brings into consciousness, a memory or thought connected with the body (part), which triggers emotions and autonomic responses, or helps noticing a muscle tension and relax it, by which previously filtered sensations are disinhibited.

Personal differences regarding attention-related body sensations were also found. Those with higher interoceptive accuracy as assessed by a heart-rate detection task reported more sensations (37). Different dimensions of attention, i.e., the role of interoceptive sensitivity, effortful and sustained attention, and selection of relevant information were also suspected to contribute to attention-related body sensations (40), while in a later study, interoceptive awareness was indeed found to be connected to attention-related body sensations, but such connection was not found with performance in a sustained attention task (61). Only one study has experimentally discovered the psychophysiological background of attention-related body sensations to our knowledge, solely examining central physiological processes. This functional magnetic resonance imaging (fMRI) study demonstrated that the attentional focus on either thumb increased the connectivity between the primary somatosensory cortex and the superior frontal gyrus, and the anterior cingulate cortex (7), and the subjectively rated

attentional strength correlated with the activation of the ventral frontopolar prefrontal cortex, whereas the experienced intensity of the sensations correlated with the activation of the dorsal frontopolar prefrontal cortex, and *inter alia* the primary somatosensory cortex, insula, and amygdala (6). In an fMRI study, body attention activated even spinal areas in expert practitioners of a body–mind method; however, body sensations were not characterized there (29).

Once a body sensation reaches consciousness, even if it was evoked by attention and originated centrally, different meanings, causes, and consequences can be attributed to it. A negative interpretation (e.g., label the sensation as a symptom of disease) can form a vicious circle with hypervigilance, where attention, expectation, and emotion worsen the complaints through a process called somatosensory amplification (3, 5). Moreover, it might even lead to the subjective experience of being sick in the absence of either any somatic pathology (medically unexplained symptoms and idiopathic environmental intolerance; 4) or harmful factors (nocebo effect; 31, 57, 58). On the other hand, a positive feedback loop can also be activated, when a body sensation is interpreted in a positive way (e.g., as a sign of healing), which can lead to positive expectations, enhance placebo effect, and contribute to trust in therapy, compliance for and effectiveness of it (10). Besides therapeutic effects, body sensations can also have hedonic value in processes of recreation and entertainment (11, 60). Moreover, they were suggested to play an essential role in self-awareness (36), the overall perception, and evaluation of body condition (20).

In sum, the clinical and psychological relevance of the attention-related body sensations (e.g., medically unexplained symptoms, placebo effect, recreation, body-awareness, and self-consciousness) is high. In complementary and naive discourse, it is often emphasized that body attention can initiate acute physiological changes at the site of attentional focus, which can help therapeutic processes, and that this attention-induced self-healing can be strengthened by various body–mind exercises (e.g., yoga and autogenic training; 10). However, the experimental testing of these hypotheses is missing.

Here, we first tested whether the intensity of attention-related body sensations is related to autonomic and somatomotor physiological processes, or to psychological traits and body–mind practice. Since body sensations were hypothetically linked to tonic motor activity, the autonomic nervous system, the motor system, and body temperature (26), our questions were as follows: how is the intensity of different attention-related body sensations related to muscle tension (as assessed by electromyography), to parasympathetic activation [as assessed by heart-rate variability (HRV)], to sympathetic activation (as assessed by skin conductance), and to local temperature at the point of attentional focus? And since attention-related sensations were linked to interoceptive accuracy by an empirical result (37), and to experience with a body–mind method by theoretical investigations (10), here, we hypothesized positive connections between the intensity of the attention-related body sensations, body awareness, and the regular practice of body–mind method.

Materials and Methods

Participants and experimental setting

Right-handed, healthy university students with no injury at the target locations ($n = 27$, 11 males, age = 22.0 ± 2.01 years) were participated in the approximately 12-min-long experiment between 9 a.m. and 6 p.m. The experiment took place in a silent laboratory room tempered to 24 °C. Participants were asked one by one to lie down on their back on the

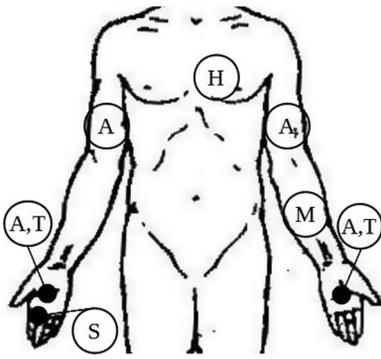


Fig. 1. Sites of attentional focus and physiological measurements: A = attentional focus, T = local temperature measurement, M = electromyographic measurement, S = skin conductance measurement, H = electrocardiographic measurement

experimental table with closed eyes, arms stretched near to the body with palms up. Before the experiment, electrodes were positioned on the subjects for the measurement of various physiological variables (see “Measurements” section), and the attentional sites were linked for local temperature measurement during the experiment. Then, through headset, we played an audio record, which guided participants to focus their attention on four different body parts (palm and upper arm on both sides, altogether four periods, also see Fig. 1) for 60 s each, in a randomized order. Attention periods were separated by 30-s-long resting periods. The entire attention section was preceded by a 90-s-long baseline period and followed by a 90-s-long end-line period. Following the end-line period, written feedback was requested about the experienced body sensations.

No prior suggestion was given about concrete sensations that might be felt (e.g., tingling), participants were informed only that the goal of the experiment was the exploration of the psychophysiological effects of paying attention to the body, which sometimes reveals different sensations and sometimes not. Moreover, as an introduction to each attention period, the audio guide asked the participants to direct their attention at the body part in question, and be aware of the sensations actually felt there. Trait-like psychological characteristics (see below) and experience of body–mind practice (see below) were assessed before the experiment. The study was approved by the Research Ethics Board of the Faculty of Education and Psychology, ELTE Eötvös Loránd University. All participants signed an informed consent form before participating in the experiment.

Measurements

Characteristics of body sensation. After the end-line period, participants were asked to write down the following aspects of their experiences with respect to each attention period separately: (1) type of the sensation(s) (no examples were given for participants), (2) intensity from 1 to 10. In the analysis, we used any body sensation label (e.g., “tingling” or “warmth”) only if that was the exact description used by the subject. Similar or related descriptors were separately treated. In the cases of not reporting a body sensation, we scored the intensity “0.”

Physiological variables. Skin conductance (right hand, palmar surface of the first phalanges of the second and third finger), electromyographic activity (on proximal and distal end of the palmar surface of the left forearm), and HRV (root mean square of the successive differences values extracted from data of three channels: right and left clavicle, and iliac crest) were continuously recorded using the NeXus-10 MKII (Mind Media, Herten, The Netherlands)

system (see Fig. 1). Local temperature of the hand in focus was manually measured every 15 s using an infrared non-contact thermometer gun (model: DT-8806C) 0, 15, 30, 45 s after and right before the attentional instruction as well.

The 19-item *Somatic Absorption Scale* was developed by David Watson to assess the proneness to continuously monitor interoceptive processes (e.g., posture, heartbeat, and bodily changes caused by sport or meal) on a 5-point Likert scale. It estimates a non-evaluative (i.e., free of negative affect), everyday aspect of body awareness, free from strong negative body experiences (pain and catastrophization). The Hungarian version of the scale was proved to be valid and showed good internal consistency (Cronbach's $\alpha = 0.84$) in a previous study (30). Its Cronbach's α coefficient was 0.80 in this study, mean score was 64.2, and standard deviation was 9.04.

Body–mind practice. The current body–mind practice (e.g., autogenic training, relaxation, yoga, tai chi, meditation, and contact dance) was assessed by the estimated average length (minutes) of such practices in a week.

Data analysis

Physiological data obtained (electrodermal activity, electromyogram, and electrocardiogram) were processed by the BioTrace⁺ software (V2014A UK). Mean values for the first 45 s of the attention and baseline periods were calculated, and then mean values were controlled by subtracting the mean value of the 45-s-long phase directly preceding the measurement (either baseline or another attention period due to randomization). Local temperature values were also averaged for the first 45 s, and controlled by subtracting the temperature measured right before the attentional instruction. Data analysis was conducted using the SPSS v21 software. Since most of the subjective ratings of body sensation were non-normally distributed, non-parametric correlations (Spearman's ρ) were used to estimate the relationships between attention-related body sensations, autonomic and somatomotor physiological processes, and psychological characteristics. Correlations between intensity of perceived sensation on the left palm and muscle tension measured on the left forearm were estimated. Similarly, connections between intensity of perceived sensation on the right palm and skin conductance on the same location were calculated. In the case of local temperature and HRV, connections with sensations for both sides were investigated. Since we did not have predictions regarding the direction of connections between physiological variables and attention-related sensations, significances were calculated with two-tailed test. On the contrary, since we hypothesized positive connections regarding body awareness and body–mind practice, significances were calculated with a one-tailed test. In all cases, correlation values were controlled for gender using the procedure described by Conover (19). Statistical significance was determined using Bonferroni-corrected p values; corrections were separately calculated for physiological (12 trials) and psychological (4 trials) variables. Degrees of freedom were 24 for every partial correlational analysis.

Results

Descriptive statistics

Tingling was experienced by 14 subjects (approximately 58% of participants; in total, 24 times out of the 108 cases), and warmth was experienced by 10 subjects (approximately 42% of participants; 21 times out of the 108 cases). Other sensations were apparent with such a low frequency (see Table I) that they could not be statistically analyzed. Therefore, here, we

Table I. List and frequency of attention-related body sensations, separately in the four locations and in total

	Right palm	Left palm	Right arm	Left arm	Total
Tingling	6	9	3	6	24
Warmth	7	5	5	4	21
Numbness	3	6	2	1	12
Heavy	1	1	1	2	5
Cold		1	2	2	5
Pulse			2	1	3
Sting	1	1		1	3
Radiate	1	1	1		3
Throbbing	2				2
Calm		1	1		2
Pain			1	1	2
As if be touched				2	2
Circulation		1			1
Pressure			1		1
Pleasant feeling		1			1
Effervescence		1			1
Twitch		1			1
Tense				1	1
Tiredness				1	1
Simply felt the body part/not specified	1		1	2	4
No sensation reported	9	5	8	7	29
Tingling and warmth together	2	2	1	2	9

focused on the two most often mentioned sensations, tingling and warmth. The intensity of tingling and warmth was valued as “0” when not specifically this sensation was reported, i.e., the intensity of tingling and warmth was “0” in 84 and 87 cases (approximately 78% and 81% of total cases), respectively. Descriptive statistical data of the assessed scales are presented in Table II.

Correlation analysis

Muscle tension measured during the period of focusing on the left forearm was tendentiously and inversely linked to the intensity of perceived warmth in the left palm (Spearman’s $\rho = -0.50$, $p = 0.009$, Bonferroni-corrected $\alpha_{10\%} = 0.0083$ and $\alpha_{5\%} = 0.0042$ in the 12

Table II. Descriptive statistics (mean and standard deviation) of the variables, psychological, and physiological variables for each attention site separately, physiological variables with uncontrolled and controlled values

	Right palm	Left palm	Right arm	Left arm	Average
Tingling intensity	1.5 ± 2.99	2.2 ± 3.36	0.4 ± 1.21	1.3 ± 2.60	1.3 ± 1.85
Warmth intensity	1.6 ± 2.89	0.8 ± 2.36	1.0 ± 2.34	0.9 ± 2.40	1.1 ± 1.77
Muscle tension (mV), uncontrolled	–	137.0 ± 476.89	–	–	–
Muscle tension (mV), controlled	–	131.5 ± 475.55	–	–	–
Skin conductance (µS), uncontrolled	7.4 ± 6.59	–	–	–	–
Skin conductance (µS), controlled	–0.5 ± 1.79	–	–	–	–
Local temperature (°C), uncontrolled	35.9 ± 1.11	35.8 ± 1.15	–	–	–
Local temperature (°C), controlled	–0.03 ± 0.41	0.04 ± 0.23	–	–	–
Heart-rate variability, uncontrolled	118.8 ± 98.01	102.4 ± 86.25	–	–	–
Heart-rate variability, controlled	17.7 ± 50.88	–3.7 ± 64.17	–	–	–

correlational analyses of physiological data), but not to perceived tingling ($\rho = -0.11$, $p = 0.6$). Skin conductance in the right palm showed no significant correlation with tingling ($\rho = -0.20$, $p = 0.3$) and warmth in right palm ($\rho = 0.21$, $p = 0.3$). Local temperature measured on the right palm was not connected with tingling ($\rho = 0.044$, $p = 0.8$) and warmth in right palm ($\rho = -0.41$, $p = 0.04$). Similarly, local temperature on the left palm was not related to tingling ($\rho = 0.10$, $p = 0.6$) or warmth in the left palm ($\rho = 0.082$, $p = 0.7$). Finally, HRV measured during attention on the right palm was not connected to tingling ($\rho = -0.073$, $p = 0.7$) and warmth in the right palm ($\rho = 0.12$, $p = 0.6$), and HRV during attention on the left palm did not correlate with tingling ($\rho = -0.10$, $p = 0.6$) or warmth in the left palm ($\rho = -0.05$, $p = 0.8$).

Body awareness showed a medium-level correlation with the average intensity of tingling (Spearman's $\rho = -0.48$, $p = 0.006$, Bonferroni-corrected $\alpha_{10\%} = 0.025$ and $\alpha_{5\%} = 0.0125$ for the four correlational analyses) but not that of warmth ($\rho = 0.16$, $p = 0.21$). Body-mind practice showed a tendentious correlation to the intensity of tingling, but not to warmth ($\rho = 0.39$, $p = 0.024$ and $\rho = 0.21$, $p = 0.15$).

Discussion

In this study, attention-related body sensations, more accurately, tingling and warmth, showed no connection with local (electrodermal activity and skin temperature) and systemic (HRV) physiological changes. Attention-related warmth sensation was

connected to decreased muscle tension. Overall intensity of tingling, as opposed to warmth, correlated significantly with body awareness, and tendentially with body–mind practice. Overall, this pattern supports the hypothesis that attention-related body sensations are mainly generated by top–down processes, possibly interacting with peripheral processes.

The presence of tingling as the most frequent attention-related sensation is in accordance with previous results, while warmth had been preceded by other sensations previously (e.g., numbness, beat/pulse, and itch; 12, 36). In “Introduction” section, we proposed three alternative explanations for such frequent occurrence of body sensations in the absence of stimulation: (1) there is a constant background activity in the sensory neurons (caused by peripheral physiological fluctuations or ectopic neuronal activation), (2) attention activates central interoceptive (somatosensory and viscerosceptive) representations, and (3) focusing on the body initiates thoughts, emotions, or homeostatic regulation, which changes peripheral physiology and activates sensory neurons.

The inverse connection between warmth and muscle tension found here is in line with previous results showing that attention-related body sensations were blocked by movement (8). It was suggested that the suppressive effect of muscle contraction on tingling and other body sensations might be mediated by top–down masking at cortical and spinal levels (8), and by muscle afferents at the spinal level (59). It is also possible that the warm sensation helped our participants to become aware of previously hidden muscle tension in this area, and release it, although it seems contradictory that tingling did not have this effect. In addition to this inverse connection between somatic sensations and muscle tension, as warmth was thought to be linked to better circulation, decrease in muscle tension might cause increased local circulation by lowering the obstructive physical pressure exerted by a contracted muscle.

Local temperature, which is mainly determined by dermal circulation regulated by the sympathetic nerves (28), showed no connection to body sensations, although increased circulation was thought to be linked to tingling and warmth (49).

Skin conductance, an indicator of sympathetic activation, and HRV, an indicator of parasympathetic activation, were neither connected to the intensity of body sensations. Previous findings on the connection between somatic sensations and sympathetic/parasympathetic activation are inconsistent. On the one hand, increase in sympathetic activation was linked to paresthesia (e.g., tingling) and hyperesthesia (mostly hyperalgesia) in some disorders, e.g., in fibromyalgia syndrome and complex regional pain syndrome (34), whereas parasympathetic activation was linked to the suppression of body sensations (mostly in the case of pain and itch; 14, 65). On the other hand, a balance between sympathetic and parasympathetic activation (typically increased parasympathetic and decreased sympathetic activity) was thought to be a criterion of being aware of body sensations (23). Our results suggest that in healthy individuals, attention-related body sensations were not connected to autonomic activation or such activity could not be detected in the short 1-min-long periods using our methods.

Self-reported body awareness was connected to the average intensity of tingling during the experiment, which is in line with the concept of body awareness, i.e., the tendency to focus attention on and perceive somatosensory signals (30), and with the concept that top–down processes have a strong impact on interoception (9). Warmth showed no connection to body awareness; maybe this connection was hidden by the uncontrolled

variance of bottom-up processes, e.g., physiological fluctuation in temperature, while tingling was caused by a more constant physiological background activation (36).

Body-mind practice did not show connection to the intensity of warmth, and showed only a tenuous connection to tingling. Such practice was thought to create a positive expectation toward situations of body attention (2), which are believed to help the attainment of real experience about self and ideal expectations (22), and the enhancement of self-regulation (23). Perhaps this connection could be better examined in a sample of more expert body-mind practitioners.

Here, we suggested a novel experimental protocol to examine attention-related body sensations, with numerous differences compared with earlier protocols, namely the “spontaneous sensation” protocol (36). First, we avoided to give any concrete example of body sensations to be felt or any instruction to actively search for them. Second, we gave longer time to experience body sensations while focusing on a body part, 60 s instead of 15 s. The reason of this was that according to a recent pilot study, body sensations emerge 20–40 s after the instruction (7). Moreover, our subjects were asked to lie down, close the eyes, and avoid moving, to reduce noise in physiological recordings, equally to the fMRI study on attention-related body sensations (7). The supine posture might reduce the generalizability of the results to everyday situations (e.g., except relaxation or hospitalized patients), but it is also controlled for the variability among participants to be able to sit for ca. 12 min in comfort. Unfortunately, we did not test how the closely applied electrodes change body sensations (generation, alteration, and suppression); it is a task to be performed to explore the effect of an fMRI measurement on body attention and related sensations. Further studies are needed to compare the differences between these protocols, and also to involve the significant factors identified in the studies of spontaneous sensations, namely laterality, the availability of visual input from the body part in focus, and also explore the sensations emerging outside of the area in focus. Here, the absence of comparing skin conductance results from left and right body parts (since the left hand had been found to be more sensitive) and of including cases with visual input versus closed eyes (visual input could foster body sensations) could possibly contribute to the minimal significant results.

Since the procedure applied here to have enough cases for our statistical analyses, namely to value the intensity of tingling and warmth as “0” when no such sensation was reported, could possibly cause distortions in the results, a larger sample would be needed to run the correlational analyses between a reported sensation and physiological variables only in cases when the sensation was reported. A larger sample would also allow us to analyze the other types of sensations excluded here, and to compare the cases when a sensation was reported versus not reported, or the subjects who reported versus not reported any sensations.

We are aware of further limitations of this study and thus for future researches, we also recommend to involve (1) the prior expectations of the subjects regarding body sensations caused by body attention; (2) the nervous system, either centrally (electroencephalography and fMRI) or peripherally (electroneurography); (3) more detailed temporal (onset and endurance) and spatial (area and direction) characteristics of the subjective body sensations; (4) subjective interpretation, e.g., beliefs about the causes or the effects of the sensations; (5) affective state before (and after) the test, and the hedonic value of body sensations; (6) state sleepiness and biorhythm; (7) effect of social

desirability on reports; and (8) longitudinal design to explore the effect of an intervention with a body–mind method.

Acknowledgements

This research was supported by the Hungarian National Scientific Research Fund (OTKA K 109549 and K 124132). The authors would like to thank Renáta Szemerszky, Zsuzsana Dömötör, Tímea Berkes, and Raechel Drew for data collection, Szilvia Zörgő for the inspiring opinions, and Ádám Balázs Czinege and Eszter Ferentzi for the careful reading.

REFERENCES

1. Barefoot JC, Straub RB: Opportunity for information search and the effect of false heart-rate feedback. *J. Pers. Soc. Psychol.* 17(2), 154–157 (1971)
2. Barratt EL, Davis NJ: Autonomous sensory meridian response (ASMR): a flow-like mental state. *Peer J.* 3, e851 (2015)
3. Barsky AJ: The paradox of health. *N. Engl. J. Med.* 318(7), 414–418 (1988)
4. Barsky AJ: Amplification, somatization, and the somatoform disorders. *Psychosomatics* 33(1), 28–34 (1992)
5. Barsky AJ, Wyshak G, Klerman GL: The somatosensory amplification scale and its relationship to hypochondriasis. *J. Psychiatr. Res.* 24(4), 323–334 (1990)
6. Bauer CC, Barrios FA, Diaz JL: Subjective somatosensory experiences disclosed by focused attention: cortical-hippocampal-insular and amygdala contributions. *PLoS One* 9(8), e104721 (2014)
7. Bauer CC, Diaz JL, Concha L, Barrios FA: Sustained attention to spontaneous thumb sensations activates brain somatosensory and other proprioceptive areas. *Brain Cogn.* 87, 86–96 (2014)
8. Beaudoin R, Michael GA: Gating of spontaneous somatic sensations by movement. *Somatosens. Mot. Res.* 31(3), 111–121 (2014)
9. Bechara A, Damasio AR: The somatic marker hypothesis: a neural theory of economic decision. *Games Econ. Behav.* 52(2), 336–372 (2005)
10. Beissner F, Brünner F, Fink M, Meissner K, Kaptchuk TJ, Napadow V: Placebo-induced somatic sensations: a multi-modal study of three different placebo interventions. *PLoS One* 10(4), e0124808 (2015)
11. Beissner F, Marzolf I: Investigation of acupuncture sensation patterns under sensory deprivation using a geographic information system. *Evid. Based Complement. Altern. Med.* 2012, e591304 (2012)
12. Borg C, Emond FC, Colson D, Laurent B, Michael GA: Attentional focus on subjective interoceptive experience in patients with fibromyalgia. *Brain Cogn.* 101, 35–43 (2015)
13. Botto RW, Galbraith GG, Stern RM: Effects of false heart rate feedback and sex-guilt upon attitudes toward sexual stimuli. *Psychol. Rep.* 35(1), 267–274 (1974)
14. Busch V, Zeman F, Heckel A, Menne F, Ellrich J, Eichhammer P: The effect of transcutaneous vagus nerve stimulation on pain perception – an experimental study. *Brain Stimul.* 6(2), 202–209 (2013)
15. Buss AH (1980): *Self-consciousness and Social Anxiety*. W. H. Freeman & Co Ltd., San Francisco–Washington–London
16. Carver CS, Blaney PH: Avoidance behavior and perceived arousal. *Motiv. Emot.* 1(1), 61–73 (1977)
17. Carver CS, Blaney PH: Perceived arousal, focus of attention, and avoidance behavior. *J. Abnorm. Psychol.* 86(2), 154–162 (1977)
18. Carver CS, Scheier MF (1981): *Attention and Self-regulation: A Control-theory Approach to Human Behavior*. Springer, New York
19. Conover WJ (1999): Cochran’s test for related observations. In: *Practical Nonparametric Statistics* (3rd ed.), ed Conover WJ, Wiley, New York, pp. 250–257
20. Craig AD: How do you feel? Interoception: the sense of the physiological condition of the body. *Nat. Rev. Neurosci.* 3(8), 655–666 (2002)
21. Edwards MJ, Adams RA, Brown H, Pareés I, Friston KJ: A Bayesian account of “hysteria”. *Brain* 135(Pt. 11), 3495–3512 (2012)
22. Farb NAS, Daubenmier J, Price CJ, Gard T, Kerr C, Dunn BD, Klein AC, Paulus MP, Mehling WE: Interoception, contemplative practice, and health. *Front. Psychol.* 6, 763 (2015)

23. Fogel A (2013): *Body Sense: The Science and Practice of Embodied Self-awareness* (1st ed.), W. W. Norton & Company, New York
24. Gibbons FX (1990): Self-attention and behavior: a review and theoretical update. In: *Advances in Experimental Social Psychology*, ed Zanna MP, Academic Press, New York, pp. 249–303
25. Gray MA, Harrison NA, Wiens S, Critchley HD: Modulation of emotional appraisal by false physiological feedback during fMRI. *PLoS One* 2(6), e546 (2007)
26. Haenen AJM, Schmidt AJM, Schoenmakers M, van den Hout MA: Suggestibility in hypochondriacal patients and healthy control subjects. An experimental case-control study. *Psychosomatics* 38(6), 543–547 (1997)
27. Irvine E: Signal detection theory, the exclusion failure paradigm and weak consciousness—evidence for the access/phenomenal distinction? *Conscious. Cogn.* 18(2), 551–560 (2009)
28. Johnson JM, Minson CT, Kellogg DL: Cutaneous vasodilator and vasoconstrictor mechanisms in temperature regulation. *Compr. Physiol.* 4(1), 33–89 (2014)
29. Kashkoui Nejad K, Sugiura M, Thyreau B, Nozawa T, Kotozaki Y, Furusawa Y, Nishino K, Nukiwa T, Kawashima R: Spinal fMRI of interoceptive attention/awareness in experts and novices. *Neural Plast.* 2014, 679509 (2014)
30. Köteles F, Simor P, Tolnai N: A Testi Abszorpció Skála magyar változatának pszichometriai értékelése [Psychometric evaluation of the Hungarian version of the Somatic Absorption Scale]. *Mentálhigiéné és Pszichoszomatika* 13(4), 375–395 (2012)
31. Köteles F, Szemerszky R, Gubányi M, Körmendi J, Szekrényesi C, Lloyd R, Molnár L, Drozdovszky O, Bárdos G: Idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF) and electrosensitivity (ES) – are they connected? *Int. J. Hyg. Environ. Health* 216(3), 362–370 (2013)
32. Leventhal H, Brown D, Shacham S, Engquist G: Effects of preparatory information about sensations, threat of pain, and attention on cold pressor distress. *J. Pers. Soc. Psychol.* 37(5), 688–714 (1979)
33. Leventhal H, Meyer D, Nerenz D (1980): The common sense representation of illness danger. In: *Medical Psychology*, ed Rachman S, Pergamon Press, New York, pp. 7–30
34. Martínez-Martínez L-A, Mora T, Vargas A, Fuentes-Iniestra M, Martínez-Lavín M: Sympathetic nervous system dysfunction in fibromyalgia, chronic fatigue syndrome, irritable bowel syndrome, and interstitial cystitis: a review of case-control studies. *J. Clin. Rheumatol.* 20(3), 146–150 (2014)
35. Mechanic D: Social psychologic factors affecting the presentation of bodily complaints. *N. Engl. J. Med.* 286(21), 1132–1139 (1972)
36. Michael GA, Naveteur J: The tickly homunculus and the origins of spontaneous sensations arising on the hands. *Conscious. Cogn.* 20(3), 603–617 (2011)
37. Michael GA, Naveteur J, Dupuy MA, Jacquot L: My heart is in my hands: the interoceptive nature of the spontaneous sensations felt on the hands. *Physiol. Behav.* 143, 113–120 (2015)
38. Mirams L, Poliakoff E, Brown RJ, Lloyd DM: Vision of the body increases interference on the somatic signal detection task. *Exp. Brain Res.* 202(4), 787–794 (2010)
39. Misovich S, Charis PC: Information need, affect, and cognition of autonomic activity. *J. Exp. Soc. Psychol.* 10, 274–283 (1974)
40. Naveteur J, Dupuy M-A, Gabrielli F, Michael GA: How we perceive our own hands: effects of attention, aging, and sex. *Somatosens. Mot. Res.* 32(4), 227–235 (2015)
41. Naveteur J, Honore J, Michael GA: How to detect an electrocutaneous shock which is not delivered? Overt spatial attention influences decision. *Behav. Brain Res.* 165(2), 254–261 (2005)
42. Nelson RJ (2010): *The Somatosensory System: Deciphering the Brain's Own Body Image*, CRC Press, Boca Raton–London–New York–Washington, DC
43. Nummenmaa L, Glerean E, Hari R, Hietanen JK: Bodily maps of emotions. *Proc. Natl. Acad. Sci. U S A* 111(2), 646–651 (2014)
44. Parkinson B, Manstead ASR: False autonomic feedback: effects of attention to feedback on ratings of erotic stimuli. *Motiv. Emot.* 10(1), 11–24 (1986)
45. Pennebaker JW: Stimulus characteristics influencing estimation of heart rate. *Psychophysiology* 18(5), 540–548 (1981)
46. Pennebaker JW (1982): *The Psychology of Physical Symptoms*, Springer, New York
47. Pennebaker JW, Skelton JA: Psychological parameters of physical symptoms. *Pers. Soc. Psychol. Bull.* 4(4), 524–530 (1978)
48. Pennebaker JW, Skelton JA: Selective monitoring of physical sensations. *J. Pers. Soc. Psychol.* 41(2), 213–223 (1981)

49. Peper E, Holt CF (2012): *Creating Wholeness: A Self-healing Workbook Using Dynamic Relaxation, Images, and Thoughts*, Springer Science & Business Media, New York
50. Petersen S, Schroijen M, Mölders C, Zenker S, Van den Bergh O: Categorical interoception: perceptual organization of sensations from inside. *Psychol. Sci.* 25(5), 1059–1066 (2014)
51. Petersen S, Van Staeyen K, Vögele C, von Leupoldt A, Van den Bergh O: Interoception and symptom reporting: disentangling accuracy and bias. *Front. Psychol.* 6, 732 (2015)
52. Ruble DN, Brooks-Gunn J: Menstrual symptoms: a social cognition analysis. *J. Behav. Med.* 2(2), 171–194 (1979)
53. Saper CB: The central autonomic nervous system: conscious visceral perception and autonomic pattern generation. *Annu. Rev. Neurosci.* 25, 433–469 (2002)
54. Silvia PJ, Gendolla GHE: On introspection and self-perception: does self-focused attention enable accurate self-knowledge? *Rev. Gen. Psychol.* 5(3), 241–269 (2001)
55. Spanos NP, Liddy SJ, Scott H, Garrard C, Sine J, Tirabasso A, Hayward A: Hypnotic suggestion and placebo for the treatment of chronic headache in a university volunteer sample. *Cognit. Ther. Res.* 17(2), 191–205 (1993)
56. Svedman P, Ingvar M, Gordh T: “Anxiebo”, placebo, and postoperative pain. *BMC Anesthesiol.* 5(1), 9 (2005)
57. Szemerszky R, Gubányi M, Árvai D, Dömötör Z, Köteles F: Is there a connection between electrosensitivity and electrosensibility? A replication study. *Int. J. Behav. Med.* 22(6), 755–763 (2015)
58. Szemerszky R, Köteles F, Lihi R, Bárdos G: Polluted places or polluted minds? An experimental sham-exposure study on background psychological factors of symptom formation in “Idiopathic Environmental Intolerance attributed to electromagnetic fields”. *Int. J. Hyg. Environ. Health* 213(5), 387–394 (2010)
59. Takazawa T, MacDermott AB: Synaptic pathways and inhibitory gates in the spinal cord dorsal horn. *Ann. N. Y. Acad. Sci.* 1198, 153–158 (2010)
60. Tihanyi BT: A zenei bizsergés pszichofiziológiai háttere és terápiás felhasználása [Musical tingling: psychophysiological background and therapeutic use]. *Mentálhigiéné és Pszichoszomatika* 17(1), 19–36 (2016)
61. Tihanyi BT, Ferentzi E, Köteles F: Characteristics of attention related body sensations. Temporal stability, and associations with measures of body focus, affect, sustained attention, and heart rate variability. *Somatosens. Mot. Res.* (in press)
62. Valins S: Cognitive effects of false heart-rate feedback. *J. Pers. Soc. Psychol.* 4(4), 400–408 (1966)
63. Verhoeven K, Crombez G, Eccleston C, Van Ryckeghem DML, Morley S, Van Damme S: The role of motivation in distracting attention away from pain: an experimental study. *Pain* 149(2), 229–234 (2010)
64. Woll SB, McFall ME: The effects of false feedback on attributed arousal and rated attractiveness in female subjects. *J. Pers.* 47(2), 214–229 (1979)
65. Yosipovitch G, Greaves MW, Schmelz M: Itch. *Lancet* 361(9358), 690–694 (2003)