Eötvös Loránd University, Faculty of Education and Psychology

Benedek Tihanyi MD

The psychobiology of tingling and other body sensations

their connection with body attention and body awareness, with personality and psychophysiological processes

Doctoral School of Psychology
Head of the Doctoral School: Zsolt Demetrovics, DSc, university professor

Personality and Health Psychology program
Head of the program: Attila Oláh, DSc, university professor

Supervisor: Ferenc Köteles PhD, university professor
Eötvös Loránd University, Faculty of Education and Psychology, Institute of Health Promotion and Sport Sciences

A bírálóbizottság tagjai:
Elnök: Dr. Oláh Attila, egyetemi tanár
Belső bíráló: Pigniczkiné Dr. Rigó Adrien, adjunktus
Külső bíráló: Dr. Purebl György, klinikai igazgatóhelyettes, Semmelweis Egyetem Magatartástudományi Intézet
Titkár: Dr. Szemerszky Renáta, adjunktus
Tagok:
Dr. Simor Péter, adjunktus
Dr. Csabai Márta, egyetemi tanár, SZTE Pszichológiai Intézet
Póttagok:
Dr. Kökönyei Gyöngyi, adjunktus
Dr. Salavecz Gyöngyvér, adjunktus, Semmelweis Egyetem Magatartástudományi Intézet

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Tihanyi Benedek

a doktori értekezés szerzőjének aláírása

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Abstract

Attention related body sensations (ARBS) emerge without external stimulation due to focused attention on a body part, especially when the organism is resting. ARBS might play a role in numerous important phenomena, positive ones like placebo-effect and ’energy’ experiences, as well as negative ones like medically unexplained symptoms and nocebo-effect. Some of the most frequent sensations are tingling, beat/pulse, warming, cooling, and muscular stiffness. The peripheral origin of all these sensations are easy to understand except the most frequent one: tingling. Tingling is a bodily sensation experienced under a variety of conditions from everyday experiences to experimental and therapeutic situations. It can be induced by both peripheral and afferent (external stimulation, pathology) and higher cognitive (attention, expectation, emotion) processes.

The Introduction summarizes the current scientific knowledge on the neurophysiological and psychological concomitants of the tingling sensation. Since tingling has not been systematically investigated, there were only fragmented and parallel explanations of the origin of tingling. These different explanations are described, completed, and also integrated here. The integrated explanation of tingling helps also to further understand the complex psychobiological mechanisms of other ARBS, whom peripheral origin are easier to identify (e.g. heartbeat, warming) than of tingling.

A standard methodology to examine ARBS was invented and developed, and used in five studies to explore the psychological and physiological correlates of the phenomenon.

The results of the five studies involved in this work showed that attention related body sensations (ARBS) can be investigated not only in real life laboratory situations (ARBS-Test) but also in written-form, even in on-line setting. The answers given to such questionnaire (ARBS-Qu) are stable in time, and are linked to body awareness, experience with body-mind techniques. Mixed results were collected regarding the connection between ARBS-Qu and other aspects of body awareness (somatosensory amplification, body image dissatisfaction,), affect, and spirituality. However, no anticipated connection was confirmed between ARBS and mindfulness, body symptoms, well-being and vitality, absorption and openness, practice of sport, and interoceptive accuracy. Connection between ARBS and physiological variables (skin conduction, temperature, heartrate variability) was also rather indefinitive. Thus ARBS are based on a body-mind interaction with the central processes (e.g. body attention, and its trait-like form, body awareness) playing a crucial role in the phenomena. Studying them might help to understand the psychobiological interactions, and the therapeutic possibilities of body attention more.

Absztrakt

A *figyelemhez kapcsolódó testi érzetek* (attention related body sensations, ARBS) olyan testi élmények, melyek külső ingerlés nélkül bukkannak fel, amikor a figyelem egy testrészre vagy a

test egészére fókuszálódik, különösen pihenő helyzetben. Az ARBS szerepet játszhat számos fontos jelenségben, mint a placebo-hatás és “energia” élmények, vagy az orvosilag megmagyarázatlan panaszok (MUS) és a nocebo-hatás. A leggyakoribb ARBS a bizsergés, pulzus, melegedés, hűlés, izomfeszültség. Ezen érzetek perifériás eredete nyilvánvaló szinte mindegyik esetben, kivéve a leggyakoribb érzetnél: a bizsergésnél. A bizsergést a legkülönfélébb helyzetben szokták tapasztalni, a hétköznapiaktól a kísérleti és terápiás szituációkig. Kiválthatja mind perifériás és érzőrendszeri (külső ingerlés, betegség) mind mentális (figyelem, elvárás, érzelmek) folyamat is.

A Bevezetésben összegzem a jelenlegi tudományos eredményeket a bizsergés idegélettani és pszichológiai hátteréről. Mivel a bizsergésről korábban nem született szisztematikus leírás, ezért az eredetéről is töredezett részmagyarázatok léteztek csak. A különféle magyarázatokat itt összegyűjtöttem, kiegészítettem, és egységes képbe foglaltam. A bizsergés mechanizmusát bemutató egységes kép nemcsak a bizsergés, hanem a többi ARBS komplex pszichobiológiai hátterét segít megérteni.

Az ARBS kutatásához több standardizált módszert is kifejlesztettünk, majd számos vizsgálatban használtuk fel őket ahhoz, hogy az ARBS mentális és élettani vonatkozásait felfedezzük.

A disszertációmban bemutatott öt kutatásom megmutatja, hogy az ARBS kutatása nemcsak valós találkozással, laboratóriumi kísérlettel (ARBS teszt) lehetséges, hanem kérdőívesen is (ARBS kérdőív), akár online formában. Egy ilyen kérdőívre adott válaszok időben stabilnak bizonyultak, és kapcsolatot mutattak a testi tudatossággal, a test-tudat technikákban való jártassággal. Az ARBS kérdőívre adott válasz és a testi tudatosság néhány aspektusa (szomatoszenzoros amplifikáció, testképpel való elégedetlenség), ill. az affektivitás, spiritualitás közti kapcsolatról szóló eredményeim vegyesek. Az elvárt kapcsolatot nem sikerült kimutatni az ARBS kérdőívre adott válasz és a mindfulness, testi panaszok, jóllét és vitalitás, abszorpció és nyitottság, sporttevékenység, és interoceptív pontosság közt. Az ARBS és élettani változók (bőr vezetőképesség, hőmérséklet, szívritmus-variabilitás) közti szintén nem találtam kapcsolatot. Tehát az ARBS egy test-tudat kölcsönhatáson alapuló jelenség, amelyben a centrális folyamatok (pl. testi figyelem, és a vonásszintű formája, a testi tudatosság) kulcsszerepet játszanak. Az ARBS további vizsgálata segíthet mélyebben megérteni a pszichobiológiai kölcsönhatásokat, és a testi figyelem terápiás hasznát.

Personal connection, goal of the work

Since I started to practice yoga at the age of 14, body attention for mehas been equal to instant relaxation, relief of stress, a flowing and growing sensation of tingling and warm pleasure which I was told was called ‘energy’. I thought that anyone who is truly bringing the attention to their body would experience such positive effect, and the only challenge for everyone is to practice how to do it, and then to remember the presence of the body in everyday situations also. I have faced an ignorance about of the body in society, and in psychological discourses I have felt a partial absence of the body (except e.g. in affective and somatic psychology), and an even bigger absence of the positive aspects of the body, that is, I have found not many schools of sources dealing with *positive somatic psychology*. When I started attending the Institute of Health Promotion and Sport Sciences on ELTE eight years ago, it was a ‘temple’ of the body for me, constantly remembering me about my body, my body awareness. I started my research with the hope that if I explore the scientific background of body attention, and the positive sensations that emerge with body attention, then I can share my strategies how to relax, create comfort, and cope with stress with more people. Especially with those, who are sceptic about complementary methods, such as yoga, and once they hear about ‘energy’, reject the whole approach. I wanted to speak about my ‘energy experiences’ in a scientific manner, without ever mentioning the word ‘energy’ (or at least mentioning it without quotation marks).

My doctoral thesis is the fruit of this last eight years of researching body attention and body sensations. When I look back, I see myself quite motivated, ‘energetic’, since working with this topic reminded me again and again to remember my body, and to relax, and to remember my desire to make people aware of the body as a resource. Besides being enthusiastic, I also see myself being naïve. The original goal of my researches had been to prove that body sensations (tingling, warmth e.g.) arising with body attention (1) exert a positive effect on the affective state, (2) are important elements of body-mind techniques (e.g. yoga), (3) and that it can be learnt how to increase them. In my thesis I demonstrate how my original simple ‘body attention is a miracle pill for everyone’ concept became more complex, and, I hope, realistic. My goals have changed so as to review the former knowledge on body attention and accompanying body sensations, to develop and validate tools to research it, and to explore its connection with personality traits, affect, exercising sport and body-mind techniques.

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This process of maturation and creation was helped by many of my colleagues and friends, I wish to express my gratitude towards them, and also highlight some of them. I thank my supervisor Ferenc Köteles, who from the beginning supported to explore a topic

that is exciting and inspiring for me. He helped with planning the studies, by teaching how to run statistical analysis, forming my scientific writings in a clearer and more understandable manner, and also socializing me for the researcher lifestyle. I would also like to thank György Bárdos, for maintaining the spirit and reminding me the roots in the Ádám György Laboratory. I thank the whole laboratory to be such a supportive community, and not just on professional, but also on personal levels.

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1. Introduction

Please, now concentrate on a freely chosen body part (e.g. hands, ears, thighs, etc.), with the eyes closed for 10-15 seconds.
Has any sensation appeared at that body part while you were paying attention to it?
Question for attention-related body sensations (developed by Köteles & Tihanyi)

Our knowledge concerning the origin and maintenance of body sensations and symptoms is far from complete. According to the traditional view, also called 'naïve realism' (Costa & McCrae, 1985) or 'the biomedical model' (Cioffi, 1991), body sensations and symptoms rely on sensory processes, which can be modified by higher cognitive factors, e.g., attention, affect, expectations. This concept is applied by the majority of symptom perception models (Gijsbers van Wijk & Kolk, 1996, 1997; Kolk, Hanewald, Schagen, & Gijsbers van Wijk, 2003; Pennebaker, 1982; Rief & Barsky, 2005). In certain cases, such as hypnosis and hallucinations, however, perception without a sensory background might also occur. In other words, perception may also be determined exclusively by mental processes, such as memory or expectations (R J Brown, 2004). The role of higher cognitive processes in the perception of the body is supported by empirical results showing that the accuracy of detection, also called interoceptive accuracy, is independent of the conscious representation of the body, i.e., interoceptive or body awareness (Ainley & Tsakiris, 2013; Ceunen, Van Diest, & Vlaeyen, 2013; Emanuelsen, Drew, & Köteles, 2015; Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015). Beyond its theoretical importance, this issue has serious practical implications, for example in the case of medically unexplained symptoms, in idiopathic environmental intolerances, in the nocebo phenomenon and in the placebo effect, when the origin of perceived sensations cannot be explained from a biomedical point of view.

As an example for the effect of higher cognitive processes on body perception, focused attention on a body part, especially if sustained for some seconds, often leads to the experience of emerging body sensation(s) (Michael & Naveteur, 2011). The most frequent sensations that can be felt without external stimulation are tingling, tickle, numbness, itch, beat/pulse, skin stretch, warming, cooling, muscular stiffness, flutter, and vibration (Borg, Emond, Colson, Laurent, & Michael, 2015). The psychobiological process of how focused attention on the body can reveal the heartbeat, or the temperature of the body might seem obvious. However, in the case of tingling, one of the sensations

most frequently reported after focusing on the body, we do not have ready explanations for its cause. In this chapter, I will review the current scientific results about the tingling sensation. By integrating numerous relevant but fragmented scientific details on the topic, I attempt to shed more light on the complex psychobiological background of the body sensations related to body attention.

The term ‘tingling’ refers to an altered sensation localized on the surface of the skin, which is not related to pain and thermal sensations. I have chosen this broad and somewhat vague description because tingling is a private qualia-type experience, which cannot be easily verbalized and communicated (Jackson, 1982). One of the leading researcher of the field defined it as ‘it feels like you have tens of tiny ants that walk on your skin’ (Michael, personal communication). I would explain tingling as a component of the complex sensation we feel after the normal circulation returns to a numb limb, but it is not the pain (needles and pins), nor the unpleasant tension, nor the warmth. Medicine places tingling under the general term paresthesia, i.e. sensations of a person's body with no apparent physical cause (NINDS, 2017). Beyond tingling, this medical term includes further sensations, such as tickling, pricking, numbness, burning, pins and needles, and the sensation of bugs crawling underneath the skin (formication). Paresthesia characterizes neuropathy in various disorders, such as diabetic neuropathy and transient limb ischemia (Lennertz, Tsunozaki, Bautista, & Stucky, 2010). Tingling is a ubiquitous body sensation, experienced under numerous different circumstances, typically in the absence of any external stimulation (see my collection in 1. Table Common triggers for tingling, and see later in more detail). In one study, when the aforementioned broad approach was applied, an altered skin sensation evoked by attention was reported by almost two-third of participants, and no gender differences were found (B. T. Tihanyi, Ságí, Csala, Tolnai, & Köteles, 2016) (see our results later also). Attention evoked tingling showed a mediocre temporal stability in another study (B. T. Tihanyi, Ferentzi, & Köteles, 2017).

1. Table Common triggers for tingling, selected from the Introduction, see details later

Condition	**Trigger**	**Examples**
Everyday/healthy conditions	Peripheral nerve stimulation	Mechanical stimulation (e.g. hitting the funny bone, sitting on the limb) (St Onge, 2007; L. Zhang, Helander, & Drury, 1996); electrical stimulation (Kampe, Jones, & Auer, 2000); application of chemicals e.g. Sichuan pepper (Lennertz et al., 2010)
	Central nervous stimulation	Electrical stimulation of the spinal cord (Linderoth & Foreman, 1999), thalamus (K. D. Davis et al., 2000; Lenz et al., 1993) and cortical somatosensory areas (Penfield & Faulk, 1955)
	Positive emotions	Musical chills (Harrison & Loui, 2014); sexual arousal and orgasm (Mulhall, Incrocci, Goldstein, & Rosen, 2011); excitement, enthusiasm, and vitality (Ayan, 2005; Bathmaker & Avis, 2005; Gould, 1991; elevation (Haidt, 2000)
	Negative emotions	Fear, anxiety, threat anticipation (Blood, Zatorre, Bermudez, & Evans, 1999)
	Sport and other somatic practices	Runner's high (Battista, 2004); breathing exercise (Van Diest, Stegen, Van de Woestijne, Schippers, & Van den Bergh, 2000)
Pathological causes	Somatic disease	Nerve compression and peripheral neuropathy (Nordin, Nyström, Wallin, & Hagbarth, 1984); somatosensory epileptic seizures (Mauguiere & Courjon, 1978); fibromyalgia (Martínez-Lavín, 2001; Vincent et al., 2013); urticaria (Wakelin, 2001); hypoglycemia (Towler, Havlin, Craft, & Cryer, 1993); phantom limbs (Ehde et al., 2000)
	Mental disease	Medically unexplained symptoms (Hartman et al., 2013); withdrawal in addiction (Fagerstrom & Schneider, 1989)

Healing interventions	Mind-body therapy	Autogenic training (M. Davis, Eshelman, & McKay, 2008; Luthe & Schultz, 1990); relaxation (Porter & Omizo, 1984; Raingruber & Robinson, 2007; Rapp, Thomas, & Leith, 1984; J. C. Smith, Amutio, Anderson, & Aria, 1996; Wilk & Turkoski, 2001); biofeedback (Stoyva & Budzynski, 1979); acupuncture (Hui et al., 2007; Kong et al., 2007); yoga (Greyson, 1993b, 1993a; Levine, 2008); taichi (Chuckrow, 2015); reiki (Miles & True, 2003); massage (Satpute, 1989)
	Other methods	Suggestion (Spanos, Stenstrom, & Johnston, 1988), hypnosis (Spiegel & Bloom, 1983; Surman, Gottlieb, Hackett, & Silverberg, 1973), meditation (Buie & Blythe, 2013; Murdock, 1978); local anesthetics (Al Luwimi, Ammar, & Al Awami, 2012), general anesthetics (Kaufman, Galili, Furer, & Steiner, 1990)
Other casues	Scientific experiment	Rubber hand illusion (Acerra & Moseley, 2005; Moseley, Gallace, & Spence, 2012); focusing attention on body (Naveteur, Dupuy, Gabrielli, & Michael, 2015)

The literature proposes different and parallel models for the etiology of tingling, determined by the trigger situations which are examined. According to the 1) afferent model, tingling is caused by bottom-up processes. The 2) attention-disclosed model states that a background sensation is already coming from the body, but focussing attention there discloses it. While the 3) attention-evoked model thinks that central processes can create the tingling sensation, without any peripheral input. Tingling caused by motor (somatic or autonomic) effector commands are best understood by the 4) efferent model. Once a model is applied in a scientific work, the other processes seem to be forgotten, leading to inaccuracies in some cases. Therefore, I will introduce the four models in detail, and based on them I draw an integrated complex picture on the etiology of tingling.

1.1 The afferent model of tingling

1.1.1 Peripheral nervous processes

Paresthetic non-painful tingling has been reported in patients suffering from disorders of peripheral nerves, dorsal roots, and the dorsal column of the spinal cord, and was related to spontaneous aberrant bursting activity of large myelinated sensory neurons from the skin (Nordin et al., 1984). In one study, the excitability of mechanoreceptors was increased at the ends of damaged nerves, and sensory axons of these nerves generated ongoing ectopic activity around the site of injury independently from external stimulation (Koltzenburg, 2005; Nordin et al., 1984).

Tingling sensations can be induced by a variety of mechanical stimulations (Choyce et al., 2001; Estebe, Le Naoures, Chemaly, & Ecoffey, 2000; Lennertz et al., 2010). When body weight rests on a body part for too long, the total blood flow is usually not decreased significantly; however, the local supply of nutrients and oxygen for the sensory nerves becomes insufficient, which causes ectopic neuronal activity responsible for tingling (St Onge, 2007; L. Zhang et al., 1996). Tingling as a result of altered nerve function is also frequently observed, for example, when a nerve is chemically anesthetized (Al Luwimi et al., 2012). Tingling can also be induced by electrical nerve stimulation in a frequency-dependent manner; lower stimulation frequencies were perceived as small pricks, while higher frequencies cause non-painful tingling (Kampe, Jones, & Auer, 2000). The increasing intensity of dermal electrical stimulation evokes three different sensations with consecutive sensory thresholds: tactile sensation, tingling, and pain (Francini, Zoppi, Maresca, & Procacci, 1979). The large Aβ nerve fibers are the easiest to excite, while for the activation of the thinner Aδ and C fibers increased electrical stimulation is needed (Rutecki, Wernicke, & Terry Jr, 1994). These results suggest that mainly the thin fibers are involved; however, the activation of a single Aβ nerve fiber in the human arm was also associated with tingling and related sensations (Ara, Hwang, Song, & Khang, 2012; Ochoa & Torebjörk, 1983).

Tingling sensation can also be induced by local application of an active compound of Sichuan pepper, hydroxy-α-sanshool. The nerve fibers responding to sanshool are rapidly adapting Aβ and Aδ, and also slowly adapting C fibers; the typical activation pattern is bursting (Lennertz et al., 2010). Sanshool-induced activation is mediated through the closing of two-pore-domain potassium (KCNK) channels, whose contribution to bursting

activity is well-known (Bautista et al., 2008; Enyedi & Czirják, 2010; Lennertz et al., 2010). A synthetic sanshool derivative, isobutylalkenyl amide also induced tingling sensation, and enhanced mechanical but not thermal sensitivity, highlighting the role of mechanoreceptors in this effect (Albin & Simons, 2010; Klein et al., 2011).

Finally, tingling is also a leading symptom in the first stage of urticaria (Wakelin, 2001), where it is mediated by histamine, another identified modulator of KCNK (Jacklet & Tieman, 2004). Tingling in various body areas can also be triggered by inhaling nitrous oxide (N_2O) (Kaufman et al., 1990), another well-known activator of some types of KCNK (Gruss et al., 2004).

1.1.2 Spinal cord processes

Paresthesia and pain caused by peripheral nerve injury or mechanical pressure has been linked to hyperexcitability of WDR (Wide Dynamic Range) neurons in the spinal cord (Al Luwimi et al., 2012; Lennertz et al., 2010; Linderoth & Foreman, 1999). WDR neurons are multimodal sensory neurons in the dorsal horn, that respond to mechanical, thermal, chemical, and nociceptive input in an intensity-dependent manner (Al Luwimi et al., 2012).

Dermal application of isobutylalkenyl amide was also found to activate the WDR neurons (Sawyer et al., 2009). In the same study, all WDR neurons were also activated by other compounds (mustard oil and capsaicin) evoking a different effect, which supports the hypothesis that there are no tingling-specific secondary sensory WDR neurons. Therefore I propose that information about tingling might be coded in the spatial or temporal activation pattern. Direct electrical stimulation of the spinal cord by epidural electrodes reduced pain and substituted it with tingling that was usually perceived as pleasant (Linderoth & Foreman, 1999).

1.1.3 Subcortical and cortical processes

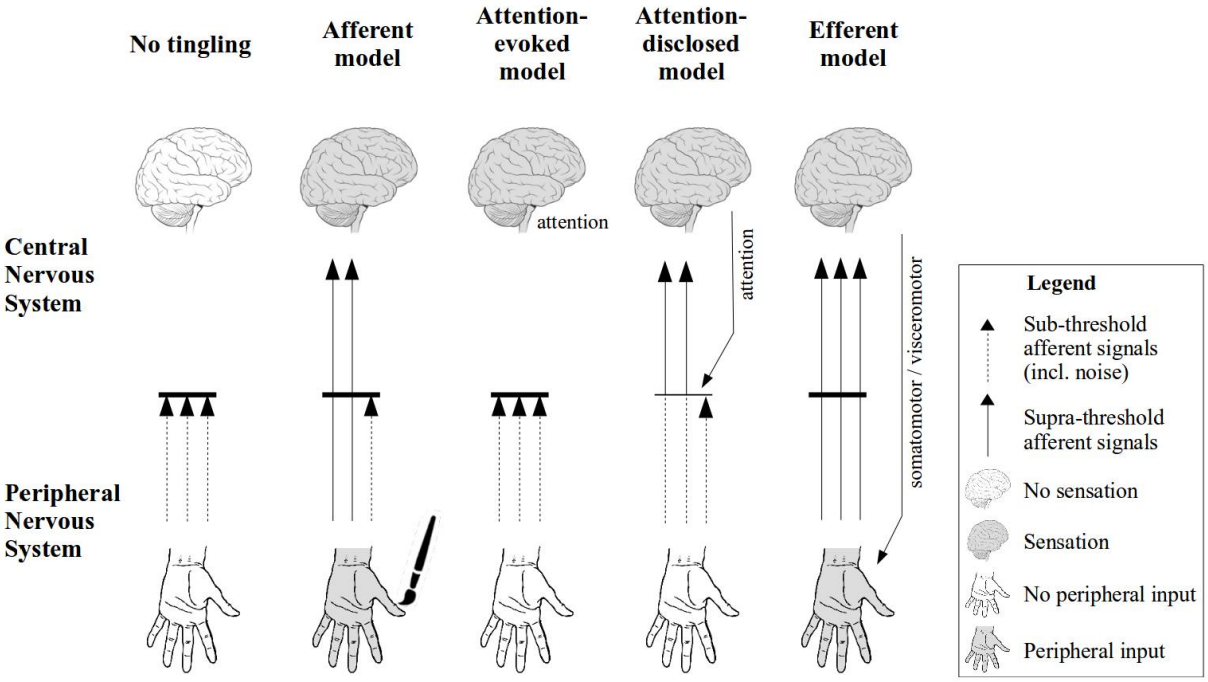
Since tingling is a conscious somatosensory experience, its central mediating structure should include the somatosensory thalamus as well as one of the following two cortical regions: (1) the primary and/or secondary somatosensory cortices and (2) the insular or "homeostatic sensory" cortex (Craig, 2002; Saper, 2002). In fact, the primary somatosensory cortex was involved in the conscious experience of tingling induced by ulnar electric stimulation in an fMRI study (Kampe, Jones, & Auer, 2000), whereas transcranial magnetic stimulation of the same area suppressed tingling (McKay, Ridding,

& Miles, 2003). Patients with epileptic seizures in cortical somatosensory regions often experience paroxysmal tingling and other somatic sensations (Mauguiere & Courjon, 1978). A number of experiments applying direct electrical stimulation have shown that stimulation of the primary and secondary somatosensory cortices can elicit tingling (Mazzola, Isnard, & Mauguière, 2006; Penfield & Gage, 1933). Similar findings were reported for the somatosensory thalamus (K. D. Davis et al., 2000; Lenz et al., 1993) and the insular cortex (Mazzola et al., 2006; Ostrowsky et al., 2000, 2002; Penfield & Faulk, 1955; Pugnaghi et al., 2011). Other regions whose direct electrical stimulation has been reported to cause tingling include the anterior portion of the supplementary motor area, the cingulate motor area (Chassagnon, Minotti, Kremer, Hoffmann, & Kahane, 2008), the orbitofrontal and the ventromedial prefrontal cortex, and the inferior temporal gyrus (Selimbeyoglu & Parvizi, 2010).

To sum it up, tingling can be evoked by external stimulation or nerve damage. It is most likely encoded in a special temporal pattern, namely the bursting of somatosensory neurons, which also characterizes ectopic activation caused by a lack of nutrients and oxygen, or by external (e.g., electrical, mechanical, chemical) stimulation. On the level of the spinal cord, deeper multimodal spinal sensory neurons are activated during tingling sensation, whereas a tingling-specific neuronal population has not been identified. The key brain areas involved in the perception of tingling are those known from interoceptive processes in the broader sense, i.e. somatosensory cortices, insula, and somatosensory thalamus.

This leads to our first out of four model for the emergence of tingling. I will refer to it as *the afferent model of tingling*. It states that tingling is triggered by and requires afferent signals (1. Figure). This reasoning is in line with the widely applied biomedical model and the various models of symptom perception presented in the introduction. Naturally, the involvement of higher cognitive processes such as attentional biases and expectations

can not be excluded. According to the afferent model, however, higher cognitive factors always rely on and process the available sensory information.



1. Figure: The most important characteristics of the four models explaining various aspects of the tingling phenomenon.

No tingling: In the absence of external input and modulating brain activity afferent signals are suppressed by the central nervous system (black line) and remain sub-threshold.

Afferent model: Afferent signals from external stimulation reach the brain and are perceived as tingling. Attention-evoked model: Body-focused attention activates central representations of a body part and tingling is perceived in the absence of peripheral input.

Attention-disclosed model: Body-focused attention opens the gate for intrinsically sub-threshold afferent signals and tingling is perceived in the absence of peripheral input. Efferent model: Somatomotor and visceromotor activity leads to changes in the periphery generating input that is perceived as tingling. In general, the attention-disclosed model can explain most empirical results found in the literature.

Retrieved from our narrative review paper (B. T. Tihanyi, Ferentzi, Beissner, & Köteles, 2018).

1.2 Attention-related tingling models

1.2.1 Spontaneous sensations and expectations

It is an everyday experience, corroborated by empirical studies, that focusing one's attention on a body part can give rise to various 'spontaneous sensations' (SPS) including tingling (Beaudoin & Michael, 2014; Michael & Naveteur, 2011; Michael, Naveteur, Dupuy, & Jacquot, 2015; B. T. Tihanyi et al., 2018). Results about the effect of age and gender were mixed, but a recent piece of research showed no connection between age and gender, and SPS (Naveteur et al., 2015). A moderating effect of the direction of the head and the eyes towards the body part in focus on SPS has also been described (Hsiao & Vega-Bermudez, 2002; Michael & Naveteur, 2011). Interestingly, external stimulation or

peripheral pathology is not a prerequisite for the tingling sensation in such cases. Good heartbeat-perceivers reported more numerous and more intense SPS (Naveteur et al., 2015).

During the so-called somatic signal detection task (SSDT), healthy participants are asked to detect near-threshold vibratory tactile stimulation. In this test participants often report erroneously vibratory sensations in the absence of any external stimulus, which may be due to an increased awareness of internal sensations that are then confused with the external stimulation (Mirams, Poliakoff, Brown, & Lloyd, 2012). The internal sensation which is possibly confused by the weak vibratory stimulus in these situations is tingling (Mirams, personal communication). In fact, a tactile test which activates the exteroceptive system, performed before the SSDT inhibited erroneous skin sensations, while a heartbeat detection task which enhances interoception, enhanced them (Mirams et al., 2012). I propose that the heartbeat detection task, as it can enhance interoceptive attention, is the cause of tingling, which is also reflected in the increased prevalence of false alarms in a following SSDT. This hypothesis is supported by the findings that various characteristics of SPS correlate with interoceptive accuracy, as assessed by a heartbeat detection task (Michael et al., 2015).

Other central processes which strongly shape attention-related sensations are the subjects' expectations and information prior to the experience. An everyday example is phantom vibration, i.e. when one mistakenly perceives one's mobile phone vibrating in one's pocket (Deb, 2015). Instances of suggestion-induced tingling were also reported in therapeutic interventions. For example, in self-hypnosis interventions, the imagination of a warm and tingling sensation was successfully used to manage pain (Spiegel & Bloom, 1983), and to heal warts (Spanos et al., 1988).

Thus, higher cognitive processes, such as attention and expectations, might play an important role in the generation of tingling sensations. This is further supported by the finding that tingling was associated with higher scores on self-report instruments assessing various aspects of body focus (i.e., body awareness) in cross-sectional questionnaire studies (B. T. Tihanyi, Ferentzi, Daubenmier, Drew, & Köteles, 2017; B. T. Tihanyi, Ferentzi, & Köteles, 2017; B. T. Tihanyi et al., 2016) (see later also). In the

case of spontaneous sensations with or without the presence of near threshold external stimuli, response bias might play a pivotal role in the perception of tingling.

1.2.2 The role of attention in tingling

In a recent fMRI study on 34 healthy adults, sustained attention on SPS in the thumb gave rise to different sensations activating the primary and secondary cortical somatosensory areas and increasing the functional connectivity between the primary somatosensory cortex, the superior frontal gyrus, and anterior cingulate cortex (Bauer, Díaz, Concha, & Barrios, 2014). In another study, the self-reported strength of attention correlated with the activity in the ventral frontopolar cortex, while the intensity of SPS correlated with the activity in the dorsal frontopolar cortex, primary somatosensory cortex, premotor cortex, precuneus, temporopolar cortex, inferior parietal lobe, hippocampus, insula, and amygdala in the absence of external stimulation (Bauer, Barrios, & Díaz, 2014). The authors concluded that attention can bring into focus and enhance afferent signals of either somatosensory or proprioceptive nature that normally do not reach consciousness; in other words, an interaction between afferent and higher cognitive processes takes place.

Tingling paresthesia has been reported as a frequent non-painful symptom of phantom limb syndrome (Ehde et al., 2000), and tingling in the face was the most frequent referred sensation in traumatic nerve injury of the hand (Pourrier et al., 2010). Both findings support the concept that there is a physiological ectopic activity in the sensory pathways, which is normally suppressed, but when a sensory area loses its habitual input, the activation which propagates from adjacent sensory areas is perceived in the form of tingling.

Under everyday circumstances, the majority of body related sensory information, as well as spontaneous activity of the sensory neurons, is usually filtered out in order to free attentional resources for processing exteroceptive information (Ádám, 1998; Al Luwimi et al., 2012; Johansson & Vallbo, 1979). Attention focused on a body part can foster sensory signals to 'pop out' and reach consciousness, thus being perceived as a novel sensation (Hsiao & Vega-Bermudez, 2002; Mirams et al., 2012). Therefore, one possible model for attention-related tingling is that attention discloses tingling sensation by opening the gate for suppressed or ectopic sensory information through descending

modulatory actions (Bauer, Díaz, et al., 2014; Borg et al., 2015; Michael & Naveteur, 2011).

I will refer to this model as *the attention-disclosed model of tingling*, since attention plays the dominant role in the perception of tingling (Figure 1). An interesting question is which role is played by the background activity of the peripheral first order or central higher order sensory neurons. In experimental studies, tingling was more frequently reported from fingers and toes than from the trunk (Beissner et al., 2015), and a similar difference was found for SPS in the hand, where the most intense sensations were reported at the tips of the fingers (Michael & Naveteur, 2011). These findings are in line with the known gradient of peripheral receptor density. However, placebo-induced sensations also exhibited a topographic pattern similar to those of referred pain which points more to a central nervous process, either spinal or cerebral (Beissner et al., 2015). A left-hand dominance in SPS has also been reported, which might refer to central mechanisms (Michael & Naveteur, 2011; Naveteur et al., 2005).

It has also been proposed that higher cognitive processes may be able to directly activate bodily representations in central somatosensory areas and *generate* conscious bodily sensations without any sensory background (Beissner et al., 2015). I refer to this as *the attention-evoked model of tingling* (Figure 1). In other words, attention-evoked tingling might happen exclusively in the brain, potentially involving central representations of previous experiences (R J Brown, 2004). The phenomenon of dysynchiria, i.e. when watching the mirror image of the unaffected limb elicits pain and/or tingling in the affected side in people with complex regional pain syndrome, and the fact that tingling can be evoked in a rubber hand (Acerra & Moseley, 2005; Moseley, Gallace, & Spence, 2012) also supports this model. The process may be similar to that of sensory imagery, where recent fMRI studies have shown that imagined sensations are perceptually grounded, i.e. the cortical representations of real and imagined sensations overlap (Lucas, Anderson, Bolling, Pelphrey, & Kaiser, 2015; T. T. Schmidt, Ostwald, & Blankenburg, 2014).

This approach receives further theoretical support from the 'as if body loop' model, i.e., the hypothesized existence of a cerebral pathway that can simulate somatic states by activating cortical and brainstem sensory centers only (Bechara & Damasio, 2005; Damasio et al., 2000). Whether such intracortical activation can really occur, and higher cognitive processes alone can activate subcortical sensory areas, are both open questions.

In a recent study (Kashkouli Nejad et al., 2014), attention focused on a body part increased the neural activity in the spinal segment innervating the attended-to body area. This finding demonstrates that attention can not only inhibit filtering, i.e., allowing the processing of a larger percentage of available information, but also increase the amount of information the central nervous system receives. It is worth noting, however, that the role of ectopic activity (technically: noise) cannot be excluded, as noise is an inherent feature of complex systems such as the brain (Edwards, Adams, Brown, Pareés, & Friston, 2012; Petersen, Van Staeyen, Vögele, von Leupoldt, & van den Bergh, 2015).

I have shown that higher cognitive processes, such as attention and expectations play a pivotal role in the generation of tingling. While response bias due to expectations may explain some results from research on spontaneous sensations, attention is definitely a key factor in the generation of the tingling sensation.

I have named two different models that explain how attention is related to tingling, the attention-disclosed and attention-evoked model (Figure 1). The main difference between the two is the role played by afferent signals. In attention-disclosed tingling these signals of either somatosensory or proprioceptive nature that normally do not reach consciousness are enhanced and brought into focus. Thus they become supra-liminal. At present, it is unclear if this activity stems from peripheral or central parts of the nervous system. In attention-evoked tingling no peripheral signal is needed. Instead, attention directly activates bodily representations in central somatosensory areas, thus generating conscious bodily sensations.

It is important to note that the distinction between the two models is rather theoretical than empirical. Most phenomena and findings presented in the preceding section can be explained by either models or their interaction.

1.3 Efferent model of tingling

Besides attention, there are further central mechanisms that can generate or influence tingling. For example, somatomotor and visceromotor activity exert direct peripheral effects, such as vasodilatation and piloerection, which can stimulate peripheral afferents

by changing temperature, pH, or tissue stretch. This can provide an input for tingling, for example through closing of KCNK channels (Enyedi & Czirják, 2010).

1.3.1 The role of the somatomotor system

SPS has initially been linked to rest and in a recent experiment it was found that SPS were suppressed by moving the thumb, even after the tactile stimulus caused by this movement was controlled for (Beaudoin & Michael, 2014). In an earlier study, the paresthetic sensations during the stimulation of the median nerve were blocked by movement in a velocity dependent manner (R. F. Schmidt, Schady, & Torebjörk, 1990). Motor activity has also been reported to inhibit various sensations in restless leg syndrome (Berger, Luedemann, Trenkwalder, John, & Kessler, 2004). However, tactile sensations are not suppressed, they are rather even enhanced during specific goal-directed movements and slow movements (Juravle, Binsted, & Spence, 2017). Perhaps slow movements and static postures require the inhibition of certain aspects of the motor activity, such as unnecessary tonic muscle tension and quick movements, which in turn might turn off the otherwise active motor suppression on the somatosensory system, and thus cause rebound enhancement of body sensations. Since the aforementioned experiments involving non-tactile stimulation, i.e., SPS and electric stimulation, also required non-goal directed movements, I hypothesize that movement can have the same enhancing effect on tingling (and other SPS) as well.

One could argue that movements simply capture attention and distract it from body sensations. However, this explanation was challenged by a recent study (Juravle & Spence, 2017). Moreover, tingling caused by ulnar nerve electrical stimulation was suppressed by transcranial magnetic stimulation of the motor cortex (McKay et al., 2003), which indicates a central modulating mechanism impacting the brainstem (Beaudoin & Michael, 2014) or the spinal cord (Takazawa & MacDermott, 2010). Activating spinal motor neurons by anterior spinal cord stimulation also elicited tingling in the targeted muscles (Harkema et al., 2011), which supports the hypothesis that motor commands are accompanied by a descending sensory inhibition to filter out sensations caused by the movement. Once the movement is finished, the physiological changes, e.g., increased

circulation, can be more easily felt, like the tingling after rubbing the hands or arm circling (Tibbetts, Charbonneau, & Peper, 1987).

1.3.2 The role of the autonomic nervous system

Sympathetic activity can increase the sensitivity of peripheral C-type nociceptors, which can be a cause of tingling accompanying pain in fibromyalgia (Martínez-Lavín, 2001; Vincent et al., 2013), myofascial pain (Chandola & Chakraborty, 2009) and complex regional pain syndrome (Drummond, 2004; Martínez-Lavín, 2001). Inhibiting the sympathetic output was also found to relieve paresthesia and pain in various conditions (Linderoth & Foreman, 1999; Martínez-Lavín, 2001). However, short-term sympathetic arousal did block somatic sensations in healthy participants (Drummond, Finch, Skipworth, & Blockey, 2001).

Parasympathetic activity was also found to facilitate tingling in hypoglycemia (Towler et al., 1993). On the other hand, an inhibitory descending effect of the parasympathetic system on non-tingling body sensations was found in the case of pain (Gebhart & Randich, 1992) and itch (Yosipovitch, Greaves, & Schmelz, 2003).

Tingling and warming was associated with autonomic relaxation, i.e. an increase in the parasympathetic activity and a decrease in the sympathetic activity, in skin temperature biofeedback interventions (Barber & Adrian, 1982). However, the experimental results are scarce, and the tingling sensation during biofeedback can also be explained by the attention related models.

These findings suggest that the autonomic system in pathological peripheral processes contributes to tingling, but suppresses body sensations in healthy subjects. At this point, it is unclear if autonomic activity is able to cause tingling under physiological circumstances at all. Findings on affective processes and emotional reactions associated with tingling will provide such examples.

1.3.3 Affective processes

Tingling is linked to a variety of affective states connected to positive excitement and the feeling of being energized (Ayan, 2005; Bathmaker & Avis, 2005; Gould, 1991). It was also associated with elevation, i.e. a pleasant positive moral emotion triggered by witnessing acts of human moral virtue (Haidt, 2000). Furthermore, tingling is linked to the anticipation of a threat or the need to act during playing computer games (Mark, 2010; Tinwell, Grimshaw, & Williams, 2010) and during outdoor activity (Kowalewski, 2004;

Wattchow & Higgins, 2014). However, it can also be concomitant with fear, anxiety, and disgust (Blood, Zatorre, Bermudez, & Evans, 1999; Chamberlin, 2011; Lazarus & Mayne, 1990; Ollendick, 1998; Schoeller, 2015b; van den Bergh, Stegen, & Van de Woestijne, 1997). In a recent study, various emotions have been associated with unique patterns of the perceived activity of bodily regions (Nummenmaa, Glerean, Hari, & Hietanen, 2014). In questionnaire studies (B. T. Tihanyi, Ferentzi, & Köteles, 2017; B. T. Tihanyi et al., 2016) (see later also), tingling was found to be not related to trait negative and positive affect; however, associations with actual affective states were not measured.

As tingling or chills have been linked to a wide range of emotions, both positive and negative, as well as general arousal, it was suggested that they consist of at least two independent factors: tingling-goosebumps and cold-shivers. While the former is related to greater surprise, enjoyment and approach motivation, the latter is linked to disgust, fear, sadness, and avoidance motivation (Maruskin, Thrash, & Elliot, 2012). It was also proposed that cold-shivers had the evolutionary advantage of triggering physical contact with the aim to cease feeling cold and to find a warm body nearby, and thereby decrease social isolation (Panksepp, 1995). In contrast, the evolutionary background of tingling-goosebumps is not entirely clear. Goosebumps are useful in the thermal regulation of hairy mammals and to make the animal look bigger and stronger in fear reactions. During phylogenesis, their role might have shifted from the original functions to the expression of superiority over others (J. W. Zhang & Keltner, 2016) and respect (Maruskin et al., 2012). Others consider chills as a part of the emotional response to the satisfaction of a drive to organize new external stimuli into a coherent cognitive construct, thus labeling mental models as approved and justified (Schoeller, 2015a, 2015b).

The actual mechanisms behind affect-related tingling might be better illuminated by the deeply researched example of hedonic experiences. Emotional peak experiences are often accompanied by tingling or chills. Within this category, music appears to be the most frequent trigger of chills, experienced mostly at the neck and the arms (Harrison & Loui, 2014). However, non-musical sounds, movies, tastes, and touches were also able to evoke chills, measured both by subjective report and sympathetic activation; moreover, ‘mental

chills', i.e., chills induced by mere recall of a pleasant memory, were also described (Grewe, Katzur, Kopiez, & Altenmüller, 2010).

A related phenomenon is the recently described autonomous sensory meridian response (ASMR) (Barratt & Davis, 2015). It is characterized by a static tingling sensation originating from the back of the head, then propagating to the neck, shoulder, arm, spine, and legs, which makes people feel relaxed and alert. Similar to chills, it can be triggered by a variety of external stimuli, but also by internal triggers, such as focusing attention, recalling the memory of a previous ASMR, meditating, or changes of mood or state of mind. It is also connected to the experience of intimacy, flow, or mindfulness (Kobayashi, 2015).

Concerning the nervous system background, a neuroimaging study has shown that the intensity of chills correlated with activity of the ventral striatum and the orbitofrontal cortex (i.e., the centers of the reward circuitry), insula, and anterior cingulum (Blood & Zatorre, 2001). It is possible that emotional involvement evokes sympathetic arousal, which in turn is perceived as a tingling sensation (Grewe et al., 2010). The hypothesis that pleasant tingling is caused by emotional processes, and not the other way around, is supported by the fact that most people experiencing ASMR reported positive emotions during listening to music even in the absence of tingling (Barratt & Davis, 2015).

Sexual arousal and orgasm are also often accompanied by tingling (Basson et al., 2003; Gould, 1991; Mulhall, Incrocci, Goldstein, & Rosen, 2011; Rosen, Phillips, Gendrano, & Ferguson, 1999). Sexual deprivation on the other hand has been reported to lead to tingling sensations during autogenic training, especially near the hips (Luthe & Schultz, 1990).

Tingling also characterizes positive experiences during intense physical activity, e.g. runner's high (Battista, 2004; Pringle, 2009), after the consumption of drugs, e.g. cocaine, morphine, and other agonists of endogenous opioid receptors (Green et al., 2009; Kaye, Darke, & Topp, 2001; Mitchell, White, Somogyi, & Bochner, 2003; Walsh, Strain, Abreu, & Bigelow, 2001). In these cases, the etiology of tingling could be that the ligand of the opioid receptors (either endogenous or exogenous) changes peripheral physiology, or directly activates the peripheral or spinal sensory neurons (Hess, 2001). However, the cerebral somatosensory areas can also be activated by the ascending reward system (Boecker et al., 2008). In the case of withdrawal in addiction, which is also characterized by tingling (Fagerstrom & Schneider, 1989; Giakas & Davis, 1997; Hirschman, 1992;

Malhotra & Bhola, 2014; Merry & Zachariadis, 1962; Senay, Alford, & Kaphingst, 2012), autonomic arousal might play the key role.

In sum, tingling reported in various emotional and hedonic states might be explained by central (somatomotor and visceromotor) commands, which cause changes in peripheral tissues, which activate the afferent nerves. The same efferent system might modulate the afferent processes on higher levels also. I refer to this as *the efferent model of tingling* (Figure 1), since efferent, i.e. motor, effects are the main cause for the emergence of the sensation.

It is worth mentioning that 'as if body loops' or simulation of peripheral events (described in 3.2.) due to central modulation of the somatosensory areas might also contribute here. The central modulation seems to be linked to the reward system: during a somatosensory discrimination task on electrically induced tingling, the dopaminergic projection from the reward system reactivated the primary somatosensory cortex when a correct answer was rewarded, and mediated the trial-by-trial improvement of somatosensory discrimination skills (Pleger et al., 2009).

1.4 Therapeutic aspects: medically unexplained symptoms and body-oriented therapies

Beyond being a frequent sign of neurological disorders, tingling is also among the complaints of medically unexplained symptoms (MUS) (Hartman et al., 2013). Related phenomena are also characterized by tingling, e.g. non-specific side effects of medication, also called nocebo effect (Abbott, Afshar, Berger, & Wackers, 2003; Gowan & Roller, 2015), and idiopathic environmental intolerance attributed to electromagnetic fields (Ferenc Köteles, 2013; Szemerszky, Gubányi, Árvai, Dömötör, & Köteles, 2015; Szemerszky, Köteles, Lihi, & Bárdos, 2010).

Interestingly, tingling can also be a desirable outcome, as evidenced by numerous body-oriented psychotherapeutic and complementary healing and preventive methods, such as autogenic training (M. Davis et al., 2008; Luthe & Schultz, 1990), relaxation (Porter & Omizo, 1984; Raingruber & Robinson, 2007; Rapp et al., 1984; J. C. Smith et al., 1996; Wilk & Turkoski, 2001), biofeedback (Stoyva & Budzynski, 1979), suggestion (Spanos et al., 1988), hypnosis (Spiegel & Bloom, 1983; Surman et al., 1973), meditation (Buie & Blythe, 2013; Murdock, 1978), acupuncture (Hui et al., 2007; Kong et al., 2007), yoga (Greyson, 1993b, 1993a; Levine, 2008), taichi (Chuckrow, 2015), reiki (Miles & True,

2003; Shiflett, Nayak, Bid, Miles, & Agostinelli, 2002), and massage (Satpute, 1989). Some of these approaches interpret tingling as the presence or flow of energy, also called qi or prana (Hui et al., 2007; Raingruber & Robinson, 2007; B. T. Tihanyi et al., 2018). While this paradigm is used by a growing number of complementary healers and patients, the scientific explanation of energy experiences is scarce. I propose that tingling during these interventions can be caused by (1) attention related processes; (2) changes in peripheral physiology, e.g. during relaxation, static postures and slow exercises, or deep breathing (Van Diest, Stegen, Van de Woestijne, Schippers, & Van den Bergh, 2000), brought about by autonomic and somatomotor self-regulation and affective processes (e.g. relaxation and happiness fostered by the thought that tingling means 'the body is healthy and keeps me alive'); and (3) movement related sensory enhancement.

In the cases when tingling is categorized and interpreted in a positive way, it can lead to positive expectations, enhance placebo-effects, and contribute to compliance and effectiveness by raising trust in the therapy (Beissner et al., 2015). If the interpretation is negative, however, it can contribute to the nocebo effect. Besides healing interventions, during recreational activities, e.g. practicing sport, attending a musical or other cultural event, following a healthy diet, fostering body attention can help to intensify pleasant body sensations, to savor the comforting moments, and thereby deepen the positive experience (Ritchie & Bryant, 2012; B. T. Tihanyi, 2016), and increase motivation to return again to this activity.

In conclusion, the same (or a very similar) phenomenon can be interpreted in a negative or a positive way, i.e., as an indicator of harmful or healthy processes, respectively. Even if a tingling sensation itself is neutral, its valence can be strongly modulated depending on the context and its interpretation. It is well-known that categorization processes can substantially contribute to both the perceived intensity and valence of the interoceptive signals (Petersen, Schroijen, Mölders, Zenker, & Van den Bergh, 2014; Petersen, van den Berg, Janssens, & van den Bergh, 2011). Moreover, expectation also influences the valence of perceived stimuli (Benedetti & Amanzio, 1997; Pennebaker, 1982).

1.5 Conclusions

The Introduction attempted to summarize the currently available knowledge on the origin of one of the most frequent attention related body sensations, tingling. Tingling is a sensation with a bewildering complexity; it can be evoked by various external stimuli, as well as by 'internal stimulation', i.e. focusing on certain body parts or being in a positive

or negative emotional state. Any model of tingling should be able to explain all these instances. Of the existing models (Figure 1), the afferent model can explain only those cases when external stimulation or peripheral pathology is present; moreover, the evoked activity needs to be intense enough to overwrite or at least substantially shape possible top-down elements of perception. The efferent model cannot provide an explanation for tingling sensations experienced in emotionally neutral states. Concerning the attention-evoked model, its scope is obviously not broad enough; for example, it cannot take external stimulation into consideration, and is not in accordance with basic neurophysiological facts, e.g., the overall presence of sensory noise at all levels of processing. The attention-disclosed model, however, appears to have a satisfying explanatory power; it can handle well cases when the sensation is evoked by external stimulation or by internal processes. A reciprocal interaction between afferent and higher cognitive processes, which seems to take place in most cases (in particular in non-experimental and non-pathological situations), is also explainable by this approach. The results of exploring the complex psychobiological background of attention related tingling can be generalized to the other attention related sensations as well (e.g. warmth, pulse, tension, with bottom-up sources more easy to identify).

After reviewing the different processes potentially contributing to tingling, some of the terms used in this field should be reconsidered. For example, the term 'spontaneous sensation' refers to the absence of external local stimulation (Michael & Naveteur, 2011). However, since subjects were instructed to pay attention to the hand, it is not spontaneous in the strict sense. Moreover, subjects in tingling related studies often receive a list of suggestive examples of concrete body sensations (Bauer, Díaz, et al., 2014; Beaudoin & Michael, 2014; Michael et al., 2011, 2015; Michael & Naveteur, 2011; Naveteur et al., 2015), which may interact with other factors in the experiment and might also increase the reported prevalence and intensity of the sensation. The term 'somatosensory experience disclosed by focused attention' (Bauer, Barrios, et al., 2014) appears to be a more precise description. Another problem with the latter term is that attention might have interacted with emotions, instead of being the only cause of sensations. Therefore I suggest to use the term attention-related body sensations for sensations experienced when focusing the attention inwards, acknowledging that the integration of various parallel

processes (e.g., cognitive, emotional, peripheral activity) forms the basis of the phenomenon.

In order to provide the most completed picture on this topic, I have included all our related published studies into the Introduction chapter. Now I will describe them one by one in more detail: the Questions and Hypotheses that motivated these studies, and then provide their Methods and Results, and also Discuss them. A general discussion and a Conclusion will help the reader to see the overall message of this work.

2. Study #1 'Sports'

In this study we investigated various mental correlates of physical activity, and also compared the different types of physical activity. By comparing beginners and experts, we wished to identify the mental characteristics which shape sport selection, and also those which are potentially improved as a result of training in the five following physical activities: yoga, Pilates, kungfu, aerobic, and ballroom dance. ARBS was only one of the various examined characteristics.

I took part in the data collection from yoga students. Digitalization, and all the statistical analysis presented here were done by me. The final paper was published by the title 'Body Awareness, Mindfulness and Affect: Does the Kind of Physical Activity Make a

Difference?' in the European Journal of Mental Health (H-index: 5) in 2016 (B. T. Tihanyi et al., 2016).

2.1 Hypotheses and questions

I hypothesize that reporting an ARBS:

Hypothesis #1 will show no correlation with age and gender,

since the most recent study on this topic showed no connection between age and gender, and ARBS (Naveteur et al., 2015).

Hypothesis #2 will show positive correlation with body awareness,

as suggested by the attention-related models (Bauer, Barrios, et al., 2014; Beissner et al., 2015; Michael & Naveteur, 2011; Naveteur et al., 2015).

Hypothesis #3 will show positive correlation with various subdimension of (body) awareness, like:

a. somatosensory amplification (i.e. the tendency to label body sensations as unpleasant or harmful)

b. trait-like mindfulness,

Hypothesis #4 will show positive correlation with positive as well as negative affect, well-being

since both positive and negative affective states were linked to enhanced peripheral physiological processes, and interoceptive

sensory activation, as I discussed in detail at the efferent model of tingling. Especially, tingling was linked to being alert, energized.

Hypothesis #5 will show positive connection with practice of sport, namely the months passed with practicing and the frequency of practicing.

Hypothesis #6 Finally, I hypothesized that body awareness will show the strongest independent connection with ARBS, after controlling for somatosensory amplification, mindfulness, affect, practice of sport,

since body awareness is a general and neutral indicator of the tendency to focus on the body.

2.2 Methods

2.2.1 Data collection

A whole team worked on the data collection (see Acknowledgements). We contacted studios and sport centers, teachers and trainers, and asked them to help us reach potential participants, who practiced at least one of the sports we focused on. Participants could fill out our collection of questionnaires online or on paper also.

We collected data between September 2011 - April 2012. Overall, 1179 participants took part in the study (age: 30.6±10.17, 848 female, 331 male).

As in all studies, the questionnaires and tests were completed anonymously and voluntarily, participants did not receive any reward for their participation. Participants under the age of 18 years (who appeared sporadically in studies that involved online recruitment, like here in Study 'Sports') were excluded. All the studies were approved by the Institutional Ethical Board of the Eötvös Loránd University, and all participants signed an informed consent form.

2.2.2 Tools

For the original Hungarian items and scoring of the questionnaires used in this study, see **Error! Reference source not found.**.

For the internal consistency values of every applied scales in this study, see 2. Table. All the scales showed acceptable or good internal consistency.

2. Table Cronbach's alpha values of the applied questionnaires for the Sports study

Study	1 'Sports'
Body awareness (SAS)	.88
Somatosensory amplification (SSAS)	.70
Mindfulness (MAAS)	.84
Positive and negative affect (PANAS)	.72, .72
Well-being (WB)	.73

2.2.2.1 Attention related body sensation questionnaire (ARBS-Qu)

In order to explore the attention related body sensations, I needed standardized methods. The SPS experiment of Michael et al. examined only the hand, and it was applied only in laboratory settings (Beaudoin & Michael, 2014; Michael & Naveteur, 2011; Michael et al., 2015). We developed a new tool, the attention related body sensation question (ARBS-Qu) to explore the phenomenon via paper or online, and to involve other body areas besides the hands.

This first version of the ARBS questionnaire consisted of no more than one item, a yes-no question: 'Please close your eyes and concentrate on a chosen body part (e.g. hands, ears, thighs etc.). Is there any change in the sensations originating from this area when you focused your attention there? (e.g. tingling)'. It was invented by Ferenc Köteles, to explore the 'energy sensation' he felt during his practice of eastern martial arts (personal communication).

2.2.2.2 *Somatic Absorption Scale* (SAS)

The 19-item scale was developed by David Watson to measure the dispositional aspects of body attention (on posture, heart beating, etc.). He wanted to create a questionnaire that is independent from negative affectivity/neuroticism, has a single factor structure, and assesses the proneness to continuously monitor body processes (D. Watson, personal communication). The Hungarian version of the scale proved to be valid and

showed good internal consistency (Cronbach's alpha = 0.84) in a previous study (Ferenc Köteles, Simor, & Tolnai, 2012).

2.2.2.3 The *Somatosensory Amplification Scale* (SSAS) (Barsky, Goodson, Lane, & Cleary, 1988; Barsky, Wyshak, & Klerman, 1990) is a scale that assesses the tendency to experience a somatic sensation as intense, noxious, and disturbing. The SSAS evaluates sensitivity to mild bodily sensations that are uncomfortable and unpleasant, but not pathological. It consists of 10 self-rated statements that are estimated on a 5-point Likert-scale. The Hungarian version proved to be valid and psychometrically sound (F. Köteles et al., 2009).

2.2.2.4 *Mindful Attention and Awareness Scale (MAAS)* (K. W. Brown & Ryan, 2003). The 15-item scale measures the extent to which one is able to focus on the present moment in an open and non-judgmental way. Each of the items is stated inversely using a 6-point Likert scale asking the respondents of how often they find themselves acting automatically, inattentively or being preoccupied. The Hungarian version has a good internal consistency (Cronbach's alpha = 0.78) in an earlier study (Simor, Petke, & Köteles, 2013).

2.2.2.5 *Positive and Negative Affect Schedule* (PANAS) (Watson, Clark, & Tellegen, 1988) consists of two independent scales rated on a 5-point Likert scale. The negative affect scale measures the general dimension of subjective distress and unpleasant engagement that subsumes a variety of aversive mood states (e.g. guilt, fear, nervousness), while the positive affect scale assesses the extent to which a person feels enthusiastic, active, and alert. In the current study, the short (5-item) version of the scales was used (Thompson, 2007). The Hungarian version of this scale had acceptable internal consistency (Gyollai, Simor, Koteles, & Demetrovics, 2011).

2.2.2.6 *Well-being Index (WHO-5)* (Heun, Burkart, Maier, & Bech, 1999) is a valid and reliable five-item scale assessing the degree of psychological well-being over the past two weeks on a 6-point Likert scale. It estimates subjective quality of life based on positive mood (good spirits, relaxation), vitality (being active and waking up fresh and rested), and general interest (being interested in things).

Higher scores indicate higher levels of well-being (Ferenc Köteles, Kollsete, & Kollsete, 2016).

2.2.2.7 *Sport activity* was assessed by a 5-item sport questionnaire, which explores e.g. the months passed since the beginning of the sport practice, the weekly frequency of sport practice (anything the participant thought to be a physical activity or sport).

2.2.3 Statistical analysis

ARBS-Qu is one binary yes-no question, thus non-parametric correlations were used to examine the connection between the variables. The Spearman rho coefficients between these variables were then entered in a partial correlation analysis, where the effect of age and gender was controlled for (Conover, 1999). One-tailed correlational analyses were applied, since in all cases I had determined the expected direction of correlation in the hypotheses. Mann-Whitney U test was applied to determine the difference between sport groups regarding prevalence of ARBS.

The independent connection between ARBS and other variables was calculated using a binary logistic regression, with ARBS as criterion variable. Age and gender were entered as control variables in the first step. As for the predictors, the hypothesized strongest predictor, body awareness was entered in a first step, and then the other variables were entered in the second step, namely somatosensory amplification, mindfulness, spirituality, affect, frequency and duration of practice of sport (out of these variables, those were avoided which did not show a significant connection in the previous

correlational analyses). Since well-being and positive affect are strongly connected, positive affect was a priori chosen for this regression analysis.

Data analysis was conducted using the SPSS v.21 software.

2.3 Results

2.3.1 Descriptive statistics

More than two thirds of the participants reported some kind of sensation when they turned their attention to the body (3. Table).

3. Table Prevalence of attention related body sensations (ARBS) applying the ARBS-Qu

Study	1 'Sports'
ARBS: no	412 (35%)
ARBS: yes	767 (65%)
total answers	1179
missing	0

The descriptive characteristics of the other variables are shown in Table 4.

4. Table Descriptive statistics (mean ± standard deviation) of personality dimensions, aspect of physical activity.

Body awareness (SAS)	65.9±12.47
Somatosensory amplification (SSAS)	27.6±5.99
Mindfulness (MAAS)	4.0±0.65
Positive affect (PANAS)	38.8±5.86
Negative affect (PANAS)	18.2±6.20
Well-being (WB)	14.6±2.43
Months of sport practice	50.9±69.77
Weekly frequency of sport practice	2.7±2.24

Differences of ARBS in different types of physical activity

The prevalence of ARBS in different sport exercisers were as follows (in a decreasing order): yoga (0.8), Pilates (0.66), dance and kung-fu (both 0.61), and aerobic (0.53). Mann-Whitney U test revealed that yoga exercisers showed significantly higher prevalence of ARBS than the other sports, Pilates exercisers and both kung-fu and dance

exercisers showed significantly higher prevalence of ARBS than aerobic exercisers, and the difference between Pilates, kung-fu and dance was not significant (5. Table).

5. Table Difference in the 1-item ARBS between participants practicing different sports

Pairs of sports	yoga - Pilates	Pilates - kung-fu	kung-fu - aerobic	Pilates – aerobic
Z-value	-3.633	-0.937	-1.974	-2.748
p-value	.000	.349	.048	.006

2.3.2 Connection between ARBS and age, gender, personality and physical activity

According to my correlational results (see Table 6. also), ARBS showed

Hypothesis #1 no correlation with age and gender,

Hypothesis #2 weak positive correlation with body awareness (see 2. Figure also),

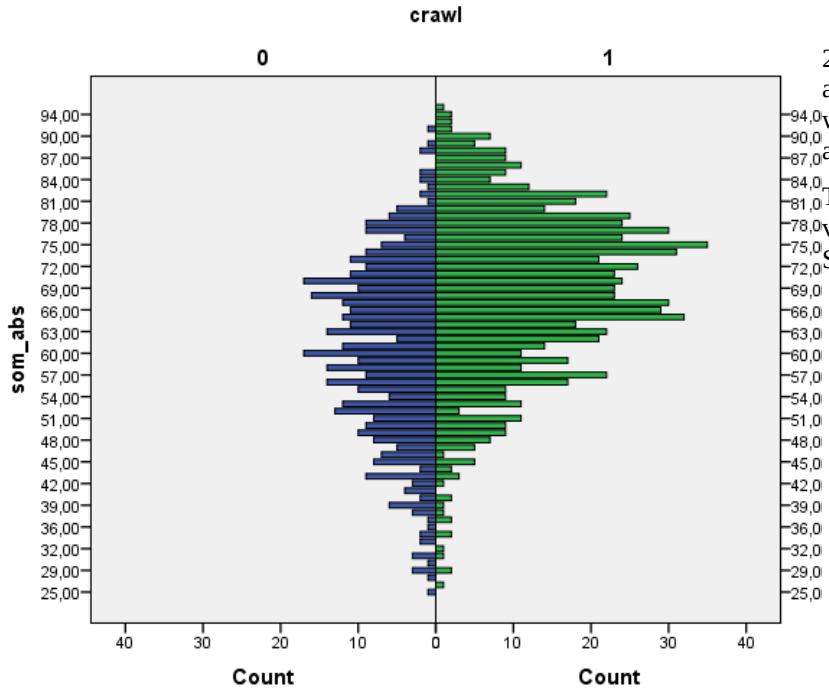
Hypothesis #3 regarding various subdimensions of (body) awareness:

a. very weak positive correlation with somatosensory amplification (i.e. the tendency to label body sensations as unpleasant or harmful)

b. no connection with trait-like mindfulness,

Hypothesis #4 very weak correlation with positive affect and well-being, and no connection with negative affect.

Hypothesis #5 no connection with practice of sport.



2. Figure Histogram of body awareness for the participants who did not report ARBS (left) and for those who did (right).

The histogram for the further variables are presented in the Supplementary materials.

6. Table Spearman correlation between ARBS- and age, gender, personality and physical activity.

After each Spearman correlation coefficients, the p-value and number of cases are given in brackets. Significance is signed in the same manner in the whole work: *: p = 0.01 to 0.05, **: p = 0.001 to 0.01, ***: p < 0.001. Numbers are bolded if they show a significant connection in the expected direction.

Age	.010 (.735, 1179)
Gender	-.021 (.479, 1179)
Body awareness (measured by the Somatic Absorption scale)	**.314*** (.000, 1170)**
Somatosensory amplification	**.152*** (.000, 1174)**
Mindfulness	.006 (.848, 1169)
Trait positive affect	**.073* (.013, 1175)**
Trait negative affect	.009 (.758, 1175)
Well-being	**.097** (.001, 1175)**
Months of sport practice	.038 (.194, 1156)
Frequency of sport practice	.028 (.332, 1167)

2.3.3 The predictors of ARBS

The binary logistic regression analysis showed that the strongest independent predictor of ARBS was body awareness (see Table 7).

7. Table Results of the logistic regression analysis predicting ARBS.
Numbers are bolded if they show a significant connection.

Nagelkerke R^2 = 0.14; $p < 0.001$	1st step		2nd step	
	Exp B	p	Exp B	p
Age	,993	,235	,992	,248
Gender	,875	,341	,859	,289
Body awareness	**1,059**	**,000**	**1,056**	**,000**
Somatosensory amplification			1,016	,216
Positive affect			1,003	,905
Months of sport practice			1,001	,320
Frequency of sport			,970	,298

2.4 Discussion

To my knowledge, this study was the first which investigated the phenomenon of attention related body sensations (ARBS) (1) with a tool that can be applied in a written form and does not require personal presence, (2) with a tool which examined the whole body and not just the hand, (3) in a Hungarian-speaking sample, (4) investigated the relationship between ARBS and validated questionnaires of body awareness, affect, and sport activity.

In accordance with my hypotheses, ARBS seemed independent from age and gender, and it was connected to body awareness, somatosensory amplification, and positive affect. However, my results disproved the hypothesized connection between ARBS and mindfulness, negative affect, and physical activity. I also found that the prevalence of ARBS was higher in those who practiced a body-mind oriented technique (yoga, Pilates, kung-fu) than in exercisers of sports not focusing so strongly on the body-mind connection (aerobic, dance); especially yoga students showed more ARBS than the

others. This suggests that body-mind techniques train the participants to pay attention to the body and notice even lighter somatic sensations or changes.

Body awareness was the strongest predictor of ARBS. This means that in this sample the tendency to pay attention to and read the body sensations in general had the strongest connection with reporting an ARBS, independently from somatosensory amplification, affect, or sport activity.

What could have exactly happened, when the participants read the ARBS-question and then gave the answer: 'yes'? As described in the Introduction in details, there are four different mechanisms which potentially underlie the reported experiences (B. T. Tihanyi et al., 2018):

1. Afferent model: some of the participants might have suffered from a (neurological) disorder or a subclinical symptom, and reported these feelings.
2. Attention-disclosed model: when the ARBS-Qu made the participants concentrate on the body part, this opened the sensory gate for otherwise suppressed peripheral body sensations, which were caused by normal physiological processes or sensory neuronal background noise. As these information reached consciousness, they were perceived as a 'change' in the feelings.
3. Attention-evoked model: It is possible, that even in the complete absence of sensory input, focusing attention on the body activated central neuronal representations.
4. Efferent model: maybe when the participants was asked to close the eyes, and pay attention to the body, for some of them this situation evoked emotions (e.g. feeling disturbed, shameful, or excited, peaceful). Also, body attention could have initiated somatic self-regulation (correct poor posture, release unneeded muscle contractions, deepening breath). The emotions and the somatic self-regulatory processes could have led to peripheral physiological changes, perceived as a change in the body sensations.

The results of Study #1 'Sports' strengthens the notion that all these different processes might play a role in the creation of ARBS. The Afferent model was not tested here, as participants were not asked about their detailed health status. But the positive results with body awareness support the relevance of the two Attention-related processes. The results of positive affect (which might be linked to the actual emotions) and that of practicing a

body-mind technique (which might be linked to the somatic self-regulatory abilities) support the relevance of the Efferent model. In accordance with the Introduction, body awareness (and thus the two attention-related processes) seems to play the key role in the phenomenon of ARBS.

However, the positive correlational connections were weak or very weak which maybe reflects the weakness of investigating ARBS with only one item and through a written form. Some of the disadvantages of the 1-item structure are that the specific sensations, the direction of change (i.e., whether it increased or decreased), the subjective intensity all remained unknown. In some cases the participants might have filled out our questionnaire in a hurry, or in a disturbing environment, or not with full concentration (all which in a real-life experimental setting can be controlled).

Furthermore, in some cases, participants could have answered randomly or distorted their answer to live up to what they anticipated the researchers expected.

It is also possible that the connection between ARBS and the examined variables are in fact weak. Our questionnaires investigated trait-like characteristics or at least long-term states (e.g. two weeks long period), while the occurrence of an ARBS might be influenced by many situational factors, like biorhythm (circadian, menses), actual pain or hunger. The connection with practicing a sport for longer period or frequently could have been hidden by the lack of inactive and unexperienced participants, since the average experience and frequency of sport were both high in this sample.

It is also worth remembering that these findings were the result of the involvement of participants doing some kind of physical activity, and therefore they should not be generalized to the whole population (since, unfortunately, the prevalence of physical activity is quite low in the general population).

Despite all these limitations, my results suggested that ARBS is prevalent in the majority of people, and shows some connection with body and affect related dimensions of mental characteristics and to practicing a body-mind oriented technique, therefore I continued my exploratory work.

3. Study #2 ‘Online’

In this study we investigated various further mental correlates of ARBS, especially body-related ones. We assessed the practice of a body-mind technique (instead of just sport in general). We also wished to reproduce the results of the previous study. Data collection took place only via internet, hence the nickname, ‘Online’.

I built up the questionnaire kit, took part in data collection (see later), I did the digital processing of the data, and also all the statistical analyses showed here. The final paper was published by the title ‘Body Responsiveness Questionnaire: Validation on a European sample, Mediation between Body Awareness and Affect, Connection with Mindfulness, Body Image, and Physical Activity.’ in the International Body Psychotherapy Journal in 2017 (B. T. Tihanyi, Ferentzi, Daubenmier, et al., 2017).

3.1 Hypotheses and questions

I tested hypotheses that were already used in the previous study, but also tested new ones (find them bolded in the list). I hypothesize that reporting ARBS:

Hypothesis #1 will show no correlation with age and gender,

since the most recent study on this topic showed no connection between age and gender, and ARBS (Naveteur et al., 2015).

Hypothesis #2 will show positive correlation with body awareness,

as suggested by the attention-related models (Bauer, Barrios, et al., 2014; Beissner et al., 2015; Michael & Naveteur, 2011; Naveteur et al., 2015).

Hypothesis #3 will show positive correlation with various subdimension of (body) awareness, like:

a. somatosensory amplification (i.e. the tendency to label body sensations as unpleasant or harmful)

b. and perceived body symptoms,

since these constructs are thought to be connected to the tendency of somatization. The attention-disclosed model and the efferent model of tingling are the basis of this hypothesis: somatic amplifiers and body symptom perceivers might have stronger body attention, and also a higher

emotional activation converted to physiological arousal, which both foster ARBS (Richard J. Brown et al., 2012; Rowlands, 2011).

c. body image dissatisfaction,

since it can foster body attention which discloses background sensations, moreover, in the experimental situation of body focus it can cause negative emotions and consequent an autonomic arousal, which fosters ARBS.

d. trait-like mindfulness,

since the ability to concentrate on the present sensory experience might foster attention-disclosed sensations

e. **body responsiveness** (i.e. the tendency to treat body as a relevant source of information in making decision, and treat body as connected to the mind),

since someone with a suppressed and ignored body is less likely to be able to pay attention to it.

Hypothesis #4 Reporting ARBS will show positive correlation with positive as well as negative affect, well-being, **vitality,**

since both positive and negative affective states were linked to enhanced peripheral physiological processes, and interoceptive sensory activation, as shown in detail when discussing the efferent model of tingling. Especially, tingling was linked to being alert, energized.

Hypothesis #5 will show positive correlation with **spirituality,**

since spirituality means also an experience of deep connection or unity with the self (not just the universe or other humans e.g.) (Fisher, 2010; Levine, 2008),

which might come together with an openness towards the body, and an awareness of body sensations.

Hypothesis #6 Reporting an ARBS will show positive connection with practice of sport and body-mind technique,

since having past experiences with such activities might have taught how to pay attention to the body, moreover, being regularly engaged in them might maintain a higher activation of the body with more vigorous body sensations.

Hypothesis #7 Finally, I hypothesized that body awareness will show the strongest independent connection with ARBS, after controlling for somatosensory amplification, body image dissatisfaction, body responsiveness, mindfulness, spirituality, affect, practice of sport and body-mind technique,

since body awareness is a general and neutral indicator of the tendency to focus on the body.

3.2 Methods

3.2.1 Data collection

A whole team worked on the data collection (see Acknowledgement also). I created an online questionnaire, which was propagated by our team via online forums excluding virtual groups which focus directly on any kind of body-mind practice, e.g. yoga.

We collected data in the Spring semester of 2015. Overall, 242 participants took part in the study (age: 32.9±13.21, 190 female, 52 male). As in all studies, the questionnaires and tests were completed anonymously and voluntarily, participants did not receive any reward for their participation. Participants under the age of 18 years (who appeared sporadically) were excluded. All the studies were approved by the Institutional Ethical

Board of the Eötvös Loránd University, and all participants signed an informed consent form.

3.2.2 Tools

For the original Hungarian items and scoring of the applied questionnaires, see **Error! Reference source not found.**.

For the internal consistency values of every applied scales in this study, see 8. Table. All the scales showed acceptable or good or excellent internal consistency, but the Somatosensory Amplification Scale and the Body Responsiveness Questionnaire were questionable.

8. Table Cronbach's alpha values of the applied questionnaires for Study 'Online'.

Body Responsiveness Questionnaire subscales: importance of interoceptive awareness (IAw), perceived disconnectedness from the body (PD).

Study	2 'Online'
Body awareness (BAQ)	.84
Somatic absorption	.87
Somatosensory amplification (SSAS)	.64
Perceived body symptoms (PHQ)	.81
Body image dissatisfaction (BIQ)	.78
Mindfulness (MAAS)	.82
Body Responsiveness (BRQ) (subscales: IAw, PD)	.67 (.83, .69)
Positive and negative affect (PANAS)	.90, .88
Well-being (WB)	.85
Vitality	.94
Spirituality (SCQ)	.95

3.2.2.1 *Attention related body sensation questionnaire (ARBS-Qu).* In this study, the same first version was applied (see in Methods of Study #1 'Sports', and Supplementary materials).

3.2.2.2 *Somatic Absorption Scale* (SAS): see in Methods of Study #1 'Sports', or in Supplementary materials.

3.2.2.3 *Body Awareness Questionnaire (BAQ) (Shields, Mallory, & Simon, 1989).* The questionnaire consists of eighteen statements that measure beliefs about one's sensitivity to normal non-emotive bodily processes, and the ability to anticipate bodily reactions. Items are scored on a seven-point Likert scale. The BAQ is considered a reliable and valid instrument for measuring self-reported attentiveness to normal bodily processes (Mehling et al., 2009). The Hungarian version showed good validity and reliability in past studies (Emanuelsen et al., 2015; Ferenc Köteles, 2014a).

3.2.2.4 *Somatosensory Amplification Scale* (SSAS): see in Methods of Study #1 'Sports', or in Supplementary materials.

3.2.2.5 *Patient Health Questionnaire Somatic Symptom Severity Scale* (PHQ-15) is a 15-item scale which measures the perceived prevalence of the most common body symptoms (e.g. headache, stomach ache, feeling tired and trouble sleeping) on a 3-point Likert scale. PHQ-15 was proposed as a diagnostic tool for a broader category of somatoform disorders (Kroenke, Spitzer, & Williams, 2002). The Hungarian version showed good psychometric properties in previous studies (Ferenc Köteles & Simor, 2013).

3.2.2.6 *Body Image Ideals Questionnaire (BIQ)* (Cash & Szymanski, 1995) is a frequently used questionnaire of body image dissatisfaction, which examines 11 physical characteristics, namely height, muscle tone and definition, body proportion, weight, chest size, physical strength, physical coordination, facial features, hair texture and thickness, skin complexion, and overall appearance. Higher scores on the BIQ indicate a greater discrepancy between the actual self and ideal self, and greater importance put on such discrepancy, both indicated

on a four-point Likert scale. Reliability of the Hungarian version was appropriate in a past study (Emanuelsen et al., 2015).

3.2.2.7 *Mindful Attention and Awareness Scale (MAAS)*: see in Methods of Study #1 'Sports', or in Supplementary materials.

3.2.2.8 *Body Responsiveness Questionnaire (BRQ)* (Daubenmier, 2005) 'assesses the tendency to integrate body sensations into conscious awareness to guide decision making and behavior and not suppress or react impulsively to them'. A factor analysis indicated the presence of two factors (Daubenmier, unpublished analyses), later supported by our analysis (B. T. Tihanyi, Ferentzi, Daubenmier, et al., 2017). The Importance of Interoceptive Awareness subscale (I-subscale) assesses the importance of using interoceptive information to regulate behavior and self-awareness, and the Perceived Disconnection subscale (PD-subscale) measures the extent of perceived disconnection between psychological and bodily states, including suppressing and reacting impulsively to them. I-subscale and PD-subscale scores were calculated separately, and for the BRQ total scores, I summed the reversed PD-subscale score and the I-subscale score. In our study, the Hungarian version showed acceptable internal consistency (B. T. Tihanyi, Ferentzi, Daubenmier, et al., 2017).

3.2.2.9 *Positive and Negative Affect Schedule* (PANAS): see in Methods of Study #1 'Sports', or in Supplementary materials.

3.2.2.10 *Well-being Index (WHO-5*: see in Methods of Study #1 'Sports', or in Supplementary materials.

3.2.2.11 *Vitality*: (Ryan & Frederick, 1997) this questionnaire is to estimate the subjective feeling of being alive and alert. It contains seven items which participants endorse on a seven point Likert scale, ranging from 'not at all' to 'very true'. Our Hungarian version has not yet been validated.

3.2.2.12 *Spiritual Connection Questionnaire (Wheeler & Hyland, 2008)*: This scale assesses an aspect of spirituality that is consistent with religious and nonreligious (e.g., New Age) interpretations of spirituality, namely the importance, experience and beliefs of spiritual connection with e.g. an inner

power, interpersonal energy, ultimate force. Participants respond to the 14 items on a 7-point scale, and high scores indicate greater spirituality. The scale was found to be unidimensional, and to have high internal consistency (a=.97) and retest reliability (r=.99) (Wheeler & Hyland, 2008). The Hungarian version had an excellent internal consistency (Ferenc Köteles & Simor, 2014).

3.2.2.13 *Sport and body-mind activity* was assessed by asking questions about the weekly frequency of sport practice (anything the participant thought to be a physical activity or sport) and body-mind method (defined as any kind of activity where body attention and inner concentration played a role, examples were autogenic training, relaxation, yoga, tai chi, meditation, contact dance), and also if the participants had any experience with a body-mind method.

3.2.3 Statistical analysis

ARBS-Qu is one binary yes-no question, thus non-parametric correlations were used to examine the connection between the variables. The Spearman rho coefficients between these variables were then entered in a partial correlation analysis where the effect of age, gender was controlled for (Conover, 1999). One-tailed correlational analyses were applied, since in all cases I had determined the expected direction of correlation in the hypotheses.

The independent connection between ARBS and other variable was calculated using a binary logistic regression, with ARBS as criterion variable. Age and gender were entered as control variables in the first step. As for the predictors, the hypothesized strongest predictor, body awareness was entered in a first step, and then the other variables were entered in the second step, namely somatosensory amplification, body image dissatisfaction, body responsiveness, mindfulness, spirituality, affect, practice of sport and body-mind technique (those which did not show a significant connection in the previous correlational analyses were avoided). Since well-being, vitality and positive affect are strongly connected, positive affect was a priori chosen for this regression analysis, mainly because it uses more items and it has the negative affect as a second subdimension. Since body awareness was assessed with two constructs, the Body Awareness Questionnaire was a priori chosen for this regression analysis. The Somatic Absorption Scale was rejected in this case because it estimates the tendency to constantly

monitor body posture and somatic events, while BAQ measures the tendency to perceive and predict somatic cycles, reactions, and change (Ferenc Köteles, 2014b).

Data analysis was conducted using the SPSS v.21 software.

3.3 Results

3.3.1 Descriptive statistics

Almost three fifth of the participants reported some kind of sensation when they turned their attention to the body (9. Table).

9. Table Prevalence of attention related body sensations (ARBS) applying the ARBS-Qu

Study	2 ’Online’
ARBS: no	99 (41%)
ARBS: yes	143 (59%)
total answers	242
missing	0

The descriptive characteristics of the other variables are shown in 10. Table.

10. Table Descriptive statistics (mean ± standard deviation) of personality dimensions, aspect of physical or body-mind activity.

Study		2 'Online'
Body awareness (BAQ)		85.6±15.33
Somatic absorption		59.9±11.62
Somatosensory amplification (SSAS)		29.7±5.71
Perceived body symptoms (PHQ)		23±4.94
Body image dissatisfaction (BIQ)		6.1±1.87
Mindfulness (MAAS)		3.9±0.74
Body Responsiveness (BRQ)		4.7±0.78
	importance of interoceptive awareness	4.9±1.04
	perceived disconnectedness from the body	3.6±1.09
Positive affect (PANAS)		35.7±6.25
Negative affect (PANAS)		20.6±7.24
Well-being (WB)		13.4±3.21
Ryan vitality		24.6±8.35
Spirituality (SCQ)		4±1.65
Weekly frequency of sport practice		3.2±2.27
Weekly frequency of body-mind practice		0.6±1.64

Regarding experience with a body-mind technique, 29% of the participants did not have any (n = 118), 31% did have at least some (n = 124), and 40% did not answer this question.

3.3.2 Connection between ARBS and age, gender, personality and physical and body-mind activity

According to my correlational results (see **Error! Reference source not found.** also), RBS:

Hypothesis #1 showed no correlation with age and gender,

Hypothesis #2 showed a very weak positive correlation with body awareness (see **Error! Reference source not found.** also),

Hypothesis #3 regarding the various subdimension of (body) awareness, ARBS:

a. showed a weak positive correlation with somatosensory amplification
b. showed a very weak positive correlation with perceived body symptoms
c. showed a very weak positive correlation with body image dissatisfaction
d. showed no connection with trait-like mindfulness,
e. showed no connection with body responsiveness, since it showed a significant although very weak connection with both its two opposing subscales, namely importance of interoceptive awareness and perceived disconnectedness from the body.

Hypothesis #4 ARBS showed the expected positive correlation with negative affect, although a very weak one. However, it also showed an unexpected negative correlation with well-being and vitality (significant but very weak), and positive affect (unsignificant). These latter results are not valid, since I used a one-tailed test, and they are significant in the unexpected direction.

Hypothesis #5 showed a weak positive correlation with spirituality,

Hypothesis #6 Reporting an ARBS showed a negative connection with practice of sport (not valid result, it opposes the hypothesis), a very weak positive connection with experience in body-mind technique, and no

connection with the weekly frequency of practicing a body-mind technique.

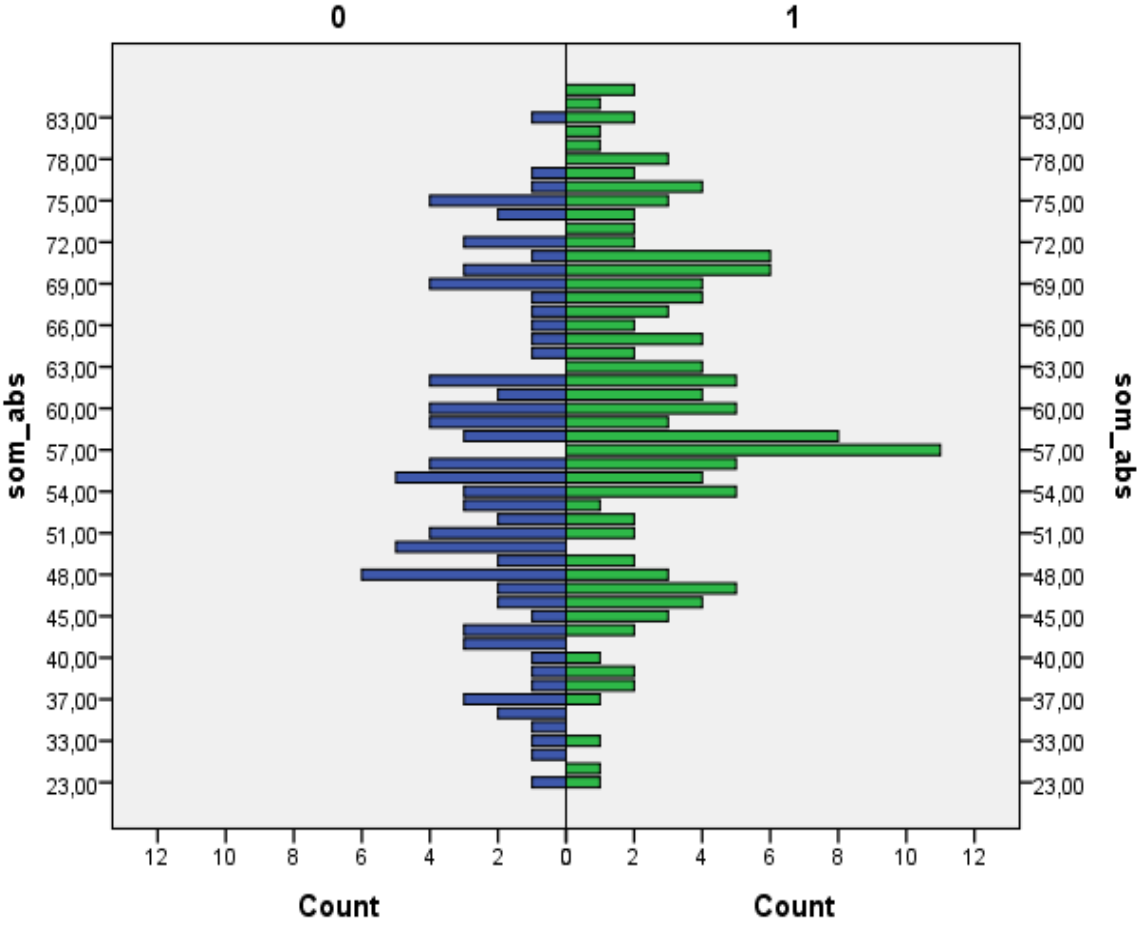
11. Table Spearman correlation between ARBS- and age, gender, personality and physical activity.

After each Spearman correlation coefficients, the p-value and number of cases are given in brackets. Significance is signed in the same manner in the whole work: *: p = 0.01 to 0.05, **: p = 0.001 to 0.01, ***: p < 0.001. Numbers are bolded if they show a significant connection in the expected direction.

Age		.053 (.412, 243)
Gender		.095 (.137, 244)
Body awareness (measured by the Somatic Absorption Scale)		**.209*** (.001 239)**
Body awareness (measured by the Body Awareness Questionnaire)		**.161** (.006, 238)**
Somatosensory amplification		**.232*** (.000,**
Perceived body symptoms		**.118* (.034,**
Body image dissatisfaction		**.124* (.028,**
Mindfulness		-.092 (.078,
Body responsiveness		.034 (.301, 238)
	importance of interoceptive awareness	**.150* (.010,**
	perceived disconnectedness from the body	.107* (.049,
Trait positive affect		-.056 (.198,
Trait negative affect		**.134* (.019,**
Well-being		-.122* (.038,
Vitality		-.108* (.048,
Spirituality		**.268*** (.000,**
Frequency of sport practice		-.122* (.047,
Experience with a body-mind technique		**.156** (.008,**
Frequency of body-mind practice		.047 (.237,

3. Figure Histogram of body awareness for the participants who did not report ARBS (left) and for those who did (right).

The histogram for the further variables are presented in the Supplementary materials.



3.3.3 The predictors of ARBS

The binary logistic regression analysis showed that the strongest independent predictor of ARBS was negative affect (see **Error! Not a valid bookmark self-reference.**). Spirituality also showed a significant positive connection, while body awareness did not have significant connection in this analysis.

12. Table Results of the logistic regression analysis predicting ARBS.

Numbers are bolded if they show a significant connection.

Nagelkerke R^2 = 0.23; p < 0.001	1st step		2nd step	
	Exp B	p	Exp B	p
Age	1,009	,393	1,023	,103
Gender	1,323	,401	,971	,947
Body awareness	**1,546**	**,010**	1,369	,213
Importance of interoceptive awareness			,885	,479
Perceived disconnectedness from the body			,919	,579
Mindfulness			1,064	,810
Spirituality			**1,480**	,001
Somatosensory amplification			1,041	,234
Body image dissatisfaction			1,137	,195
Negative affect			**1,850**	,024
Frequency of sport			**,847**	,037
Experience with a body-mind technique			1,046	,904

3.4 Discussion

The novelty of Study ’Online’ is that it did show the expected positive connection between attention related body sensations (ARBS) and body image dissatisfaction, perceived body symptoms, importance of interoceptive awareness (in decision making), and spirituality.

There was one new hypothesis which was rejected, namely that perceived disconnectedness with the body would be connected negatively with ARBS.

Regarding the hypotheses that were already tested in the previous study, ARBS is connected to body awareness, somatosensory amplification, and experience with a body-mind technique. Study ’Online’ showed a positive connection between ARBS and negative affect while did not reproduce the positive connection with aspects of positive affect (well-being, vitality). ARBS showed no connection with age, gender, and the hypothesized connections with mindfulness and sport were also missing.

The positive connection with body awareness, importance of interoceptive awareness, experience with a body-mind technique, and spirituality may give the impression thatperceiving ARBS is simply linked to a personality who is open and accepting towards the body signals, and feels deeply connected or united with the body, or to the practice of focusing on the body. However, this picture becomes more complex when those results are involved which show that ARBS is also linked to dissatisfaction with the body, feeling symptoms (discomfort and pain) in it, amplifying the negative somatic sensations, and negative affect. According to our results (showed only in Supplementary materials), the connection between ARBS and both positive/neutral and negative aspects of body awareness and affect did not originate from two distinct subpopulation of our sample. Rather, there was a positive connection between these theoretically opposing aspects of personality, e.g. importance of interoceptive awareness and spirituality were both linked to somatosensory amplification. In sum, ARBS seem to be an indicator of a personality which feels strongly linked to the body, thinks it is important to listen to the body, and at the same time is sensitive to the negative sensations and perceive symptoms more than average.

According to our logistic regression analysis, surprisingly, the strongest predictor of ARBS in this sample was negative affect, while body awareness, the hypothesized strongest predictor was ‘knocked out’ by negative affect and the other predictors. We can

explain the role of affect in ARBS based on the Introduction. According to the Efferent model, being aroused by negative emotions or negative affect (distress, anger e.g.) triggers peripheral physiological changes, via the autonomic nervous system for example, and these somatic changes pop up when get attentional focus. Alternatively, according to the attention-related models, negative affect causes an arousal and a sharper activation of awareness, which then detects more easily the otherwise suppressed body sensations.

Still, the question remains, how could have the negative affect been more important than the body awareness here? Maybe it was because the items of the Body Awareness Questionnaire used in this study concentrate on (1) perceiving concrete body processes and (2) predicting future body reactions to various influences (e.g. eating, sleeping, doing sport). These could both be independent from the tendency to feel something in the body when consciously concentrating on it.

Spirituality also had a significant independent connection with ARBS, even when controlling for experience with a body-mind technique. This implicates that the tendency to feel a special connection with others and the universe and to value such special connections is independently linked to being able to pay attention to the body and perceive somatic sensations in it, and is not mediated by involvement in meditation or other body-related spiritual practice. Frequency of sport showed a negative independent connection with ARBS, which opposed our hypothesis. One possible explanation is that in this sample of university students from bachelor program for recreation or sport management showed vigorous physical activity, and in their case, high frequency of sport comes together with the suppression of the body and a weakened ability to listen to the lighter somatic sensations.

As the data collection was very similar to Study Sports, the limitations I mentioned there apply here quite the same. The biggest difference was that here only online questionnaires were used, and maybe the disruption of filling it out was more frequent than in Study ‘Sports’, where a subsample filled out a paper-formed questionnaire. Thus, it is more probable that only those finished answering our questions and thus appeared in our data who were interested in our questions, i.e. thought that the body-mind connection is a relevant topic. Therefore, generalizing these result to the average population should be done only with caution.

4. Study #3 ‘Longi’

In this Study, we wished to explore the temporal stability of ARBS, this is why the nickname of this test-retest study is ’Longi’. We also wanted to compare, for the first time, the results of the written ARBS-Qu questionnaire and a real-life experimental method, the ARBS-Test, developed by Ferenc Köteles and the author. Another primary goal was to investigate the connection between ARBS and interoceptive (cardioceptive) accuracy, and further personality dimensions (like Openness subdimension of the Big Five, or absorption).

The secondary goal was to replicate the results of the previous studies, e.g. about body related personality characteristics, vitality, and body-mind practice. The study examined several other aspects of interoception not discussed here.

A whole team worked on this research (see Acknowledgement also). I created the online questionnaire, completed all the ARBS-Tests presented here, helped recruiting the participants, and took part in coordinating the different experiments (not all presented here) and the participants. Processing the raw data, and the statistical analyses showed here were also done by me. I carried out, too, the phenomenological categorization under the supervision of József Rácz.

The final paper in the topic of ARBS was published by the title ‘Characteristics of attention related body sensations. Temporal stability, and associations with measures of body focus, affect, sustained attention, and heart rate variability.’ in the Somatosensory & Motor Research (impact-factor: 0.909 in 2016) (Tihanyi, B. T., Ferentzi, E., & Köteles, F., 2017). The phenomenological and correlational analyses were done later, and are among the novelties of this thesis.

4.1 Hypotheses and questions

Since both the ARBS-Qu (which can be filled out without real-life meeting) and the ARBS-Test (which was performed as a real-life laboratory experiment) are new tools, I had explorative questions:

Question #1 what is the **prevalence** of ARBS assessed via ARBS-Qu, **and via ARBS-Tes**t

Question #2 **what kind of body sensations** emerge during **ARBS-Test**?

Question #3 **how many seconds does it take for ARBS to emerge?**

Question #4 **how intense and how pleasurable are they**?

Question #5 **How do the participants explain the origin or cause of the perceived ARBS during the test**?

Question #6 **How do the participants perceive the effect of turning the attention to the body during the test?**

I hypothesize that reporting ARBS on the ARBS-Qu:

Hypothesis #1 will show a positive connection with reporting ARBS during the **real-life ARBS-Test**, i.e. the number of the reported sensations.

Hypothesis #2 will be a trait-like characteristic, showing **temporal stability,** since other characteristics of interoception also showed a significant test-

retest correlation, as we concluded in another review (Ferentzi et al., 2018).

Hypothesis #3 will show no correlation with age and gender, since the most recent study on this topic showed no connection between age and gender, and ARBS (Naveteur et al., 2015).

Hypothesis #4 will show positive correlation with body awareness, as suggested by the attention-related models (Bauer, Barrios, et al., 2014; Beissner et al., 2015; Michael & Naveteur, 2011; Naveteur et al., 2015).

Hypothesis #5 will show positive correlation with various subdimension of (body) awareness, like:

a. somatosensory amplification (i.e. the tendency to label body sensations as unpleasant or harmful)

b. and perceived body symptoms, since these constructs are thought to be connected to the tendency of somatization. The attention-disclosed model and the efferent model of tingling are the basis of this hypothesis: somatic amplifiers and body symptom perceivers might have stronger body attention, and also a higher emotional activation converted to physiological arousal, which both foster ARBS (Richard J. Brown et al., 2012; Rowlands, 2011).

c. body image dissatisfaction, since it can foster body attention which discloses background sensations, moreover, in the experimental situation of body focus it can cause negative emotions and consequently an autonomic arousal, which fosters ARBS.

d. trait-like mindfulness, since the ability to concentrate on the present sensory experience might foster attention-disclosed sensations

e. body responsiveness (i.e. the tendency to treat body as a relevant source of information in making decision, and treat body as connected to the mind), since someone with a

suppressed and ignored body is less likely to be able to pay attention to it.

Hypothesis #6 Reporting ARBS will show positive correlation with affect and vitality,

Hypothesis #7 will show positive correlation with further personality traits:

a. spirituality, since spirituality means also an experience of deep connection or unity with the self (not just the universe or other humans e.g.) (Fisher, 2010; Levine, 2008), which might come together with an openness towards the body, and an awareness of body sensations.

b. **absorption** (i.e. the tendency to get fully engaged in an experience, especially as an observer of an aesthetic moment), since it might be associated with the ability to be absorbed in body experiences also

c. **Openness** (a factor of the Big Five), since openness to previously unrecognized or even weird body sensations during an ARBS experiment might foster experiencing an ARBS.

Hypothesis #8 Reporting an ARBS:

will show positive connection with practice of sport and body-mind technique, since having past experiences with such activities might teach how to pay attention to the body, moreover, being regularly engaged in them might maintain a higher activation of the body with more vigorous body sensations.

Hypothesis #9 reporting an ARBS on the ARBS-Qu will show positive correlation with heartbeat detection ability,

since good heartbeat-perceivers reported more numerous and more intense ARBS (Naveteur, Dupuy, Gabrielli, & Michael, 2015).

Hypothesis #10 I hypothesized that body awareness will show the strongest independent connection with ARBS, after controlling for somatosensory amplification, body image dissatisfaction, body

responsiveness, mindfulness, spirituality, affect, practice of sport and body-mind technique.

since body awareness is a general and neutral indicator of the tendency to focus on the body.

Hypothesis #11 I hypothesized that the same results will be observed regarding the connection of ARBS-Test (i.e. the number of the reported sensations during the real-life experiment) and the examined variables, and also its temporal stability.

4.2 Methods

4.2.1 Data collection

We collected data in the Spring and Autumn semesters of 2016. The study was realized as a part of a sport physiology course for undergraduate university students. As in all studies, the questionnaires and tests were completed anonymously and voluntarily, participants did not receive any reward for their participation. Overall, 69 participants took part in the study (age: 21.7±3.76, 31 female, 29 male), all participants were of or above the age of 18 years. Participants signed the informed consent before the measurements. They filled out the questionnaires on-line prior to real-life experiments (ARBS-Test, heartbeat detection task). At the first measurement, 62 participants filled out the questionnaire, and 59 completed the tests. The second measurement followed the first one 8 weeks later, 48 participants filled out the questionnaire, and 31 were present at the tests.

The study was approved by the Institutional Ethical Board of the Eötvös Loránd University.

4.2.2 Tools

Regarding the questionnaires, the original Hungarian items and scoring, see **Error! eference source not found.**.

For the internal consistency values of every applied scale in this study, see 13. Table. The majority of the scales showed acceptable or good or excellent internal consistency, but

the Body Responsiveness Questionnaire and its Perceived disconnectedness subscale were questionable, and the Somatosensory Amplification Scale was poor.

13. Table Cronbach's alpha values of the applied questionnaires for Study 'Longi'.

Body Responsiveness Questionnaire subscales: importance of interoceptive awareness (IAw), perceived disconnectedness from the body (PD).

Study	3 'Longi'
Body awareness (BAQ)	.79
Body awareness (SAS)	.86
Somatosensory amplification (SSAS)	.50
Perceived body symptoms (PHQ)	.76
Body image dissatisfaction (BIQ)	.75
Mindfulness (MAAS)	.81
Body Responsiveness (BRQ) (subscales: IAw, PD)	.60 (.74, .63)
Positive and negative affect (PANAS)	.84, .87
Ryan vitality	.95
Spirituality (SCQ)	.94
Absorption (TAS)	.85
Big Five (BFI) - Openness	.82

4.2.2.1 *Attention related body sensation test (ARBS-Test)*

The test was applied in a calm environment with participants in a resting sitting pose with the eyes closed. Guided by verbal instructions, participants paid attention to various body parts for 15 seconds, in a fixed order: right palm, left palm, shoulders, nape and the top of the head, face, belly, feet, chest, and a freely chosen body part 'that invites attention the most'. Immediately after each attentional period, participants described their experience by answering our questions: the quality of the sensation (e.g. tingling, warmth), the estimated starting point (0-15 seconds), the intensity and the level of pleasure/displeasure on a scale of 1-10.

4.2.2.2 *Interoceptive accuracy* is characterized most often by heartbeat detection ability.

Accuracy in perceiving heartbeats was measured here using a modified version

of the Mental Tracking Method (Emanuelsen et al., 2015; Ferentzi et al., 2017; Schandry, 1981).

Following a 15-second test trial, participants were asked to count their heartbeats for intervals of 30 sec, 45 sec, and 100 sec, with a 10 second break in between the estimates (intervals were arranged randomly). The experimenter counted the participants' actual heartbeats using a Polar watch (model RS-400) with a chest strap. All subjects were asked to breathe at a regular pace during the tracking intervals. Accuracy of heartbeat detection in a given session was calculated using the following formula: |(recorded heartbeats - counted heartbeats)/recorded heartbeats|. Interoceptive accuracy was calculated as the mean score of the three (30 s, 45 s, 100 s) heartbeat perception intervals, higher scores indicating higher levels of accuracy.

4.2.2.3 *Attention related body sensation questionnaire (ARBS-Qu).* In this study, the first version was applied again (see in Methods of Study #1 'Sports', and Supplementary materials).

Somatic Absorption Scale (SAS): see in Methods of Study #1 'Sports', or in Supplementary materials.

4.2.2.4 *Body Awareness Questionnaire (BAQ)*: see in Methods of Study #2 'Online', or in Supplementary materials.

4.2.2.5 The *Somatosensory Amplification Scale* (SSAS): see in Methods of Study #1 'Sports', or in Supplementary materials.

4.2.2.6 *Patient Health Questionnaire Somatic Symptom Severity Scale* (PHQ-15): see in Methods of Study #2 'Online', or in Supplementary materials.

4.2.2.7 *Body Image Dissatisfaction Scale* (BIQ): see in Methods of Study #2 'Online', or in Supplementary materials.

4.2.2.8 *Mindful Attention and Awareness Scale (MAAS)*: see in Methods of Study #1 'Sports', or in Supplementary materials.

4.2.2.9 *Body Responsiveness Questionnaire (BRQ)*: see in Methods of Study #2 'Online', or in Supplementary materials.

4.2.2.10 *Positive and Negative Affect Schedule* (PANAS): see in Methods of Study #1 'Sports', or in Supplementary materials.

4.2.2.11 *Vitality*: (Ryan & Frederick, 1997): see in Methods of Study #2 'Online', or in Supplementary materials.

4.2.2.12 *Spiritual Connection Questionnaire* see in Methods of Study #2 'Online', or in Supplementary materials.

4.2.2.13 *Tellegen Absorption Scale* (Tellegen & Atkinson, 1974). Absorption (not to confuse with somatic absorption, which is one aspect of body awareness, used in these studies also) is the trait to immerse into sensory (visual, audial, olfactory, etc.…) or mystical experiences or altered states of consciousness (Simor, Köteles, & Bódizs, 2011). The 34-item require answers in a yes-no form. The Hungarian version had a good internal consistency in previous studies (Simor et al., 2011).

4.2.2.14 *Sport and body-mind activity.* Physical activity for the last three months was self-estimated on a 5-point scale (with '1' meaning no regular physical activity, '5' meaning more than 3-4 hours per week). Participants answered questions about the weekly frequency of body-mind practice (defined as any kind of activity where body attention and inner concentration played a role, examples were autogenic training, relaxation, yoga, tai chi, meditation, contact dance), and also if the participants had any experience with a body-mind method.

4.2.3 Statistical analysis

ARBS-Qu is one binary yes-no question, thus non-parametric correlations were used to examine the connection between the variables. The Spearman rho coefficients between these variables were then entered in a partial correlation analysis where the effect of age and gender was controlled for (Conover, 1999). One-tailed correlational analyses were

applied, since in all cases I had determined the expected direction of correlation in the hypotheses.

The independent connection between ARBS and other variable was calculated using a binary logistic regression, with ARBS as criterion variable. Age and gender were entered as control variables in the first step. As for the predictors, the hypothesized strongest predictor, body awareness was entered in the first step, and then the other variables were entered in the second step, namely somatosensory amplification, body image dissatisfaction, physical symptoms, body responsiveness, mindfulness, spirituality, affect, openness, absorption in experience, practice of sport and body-mind technique, cardioceptive accuracy (those which did not show a significant connection in the previous correlational analyses were avoided). Since vitality and positive affect are strongly connected, positive affect was a priori chosen for this regression analysis. Since body awareness was assessed with two constructs, the Body Awareness Questionnaire was a priori chosen for this regression analysis. The Somatic Absorption Scale was rejected in this case because it estimates the tendency to constantly monitor body posture and somatic events, while BAQ measures the tendency to perceive and predict somatic cycles, reactions, and change (Ferenc Köteles, 2014b).

Data analysis was conducted using the SPSS v.21 software.

The qualitative analysis of the self-guessed origin and perceived effect of ARBS followed several stages, as in accordance with the method of interpretative phenomenological analysis (J. A. Smith & Osborn, 2004): in the first stage we read the whole list of answers a number of times. We collected those sentences and words that seemed important. Then we returned to the original answers to transform the initial notes into emerging themes or concepts taking care not to lose the connection between the participant's own words and our interpretations. Version by version we managed to compile a satisfying list of themes. The themes were given a descriptive label which conveys the conceptual nature of the answers linked to them. As the themes emerged, the original answers were checked again to ensure that the connection with what the participant had actually said was maintained. In the final stage, a table of themes was produced.

4.3 Results

4.3.1 Descriptive characteristics and statistics

Almost three fifth of the participants reported some kind of sensation when they answered the ARBS-Qu at the first measurement, and two third of those who filled out our questionnaire at the second measurement reported an ARBS (14. Table). There was a moderate stability across the two measurements, separated by eight weeks (Spearman rho = 0.50, p = 0.001, n = 41) for ARBS-Qu, and a weak stability for ARBS-Test (Spearman rho = 0.39, p = 0.02 , n = 26). ARBS reported at the questionnaire increased by time (14. Table), and ARBS reported at the test decreased by time (see later).

14. Table Prevalence of attention related body sensations (ARBS) applying the ARBS-Qu

Study 3 'Longi'	First measurement	Second measurement (8 weeks later)
ARBS-Qu: no	25 (42%)	16 (23% of total, 33% of answers)
ARBS-Qu: yes	35 (58%)	32 (46% of total, 67% of answers)
total answers	60 (86%)	48 (70%)
missing	10 (14%)	21 (30%)

During the ARBS-Test in the first measurement, there was a moderately strong connection between the results of ARBS-Qu and the number of sensations reported by the participants in ARBS-Test (among the nine body parts) (Spearman rho = .47, p = .000, n = 54).

Across the 59 participants and 9 body parts, 56 different types of sensations were reported, out of which tingling was the most frequent type of sensation (reported for 94 times), warmth was the second (67 times) and throb (44 times) was the third most frequent (15. Table).

All but one participant felt something at least at one place, most of the participants (27.1%) felt some kind of sensation at 8 places out of 9 (while 9 person felt something at all the 9 places). The most frequent place to feel something out of the 9 places (right palm, left palm, shoulders, nape and top of the head, face, belly, feet, chest, freely chosen part)

was the freely chosen part: 84% of subjects reported ARBS here. Second most frequent body parts were the feet, 80.0%,

right and left palm were 72.9% and 64.3% (respectively), the least frequent place was the chest (54.3%).

The average number of ARBS reported per body part was 0.89 (minimum:0, maximum: 2.2, reached by one participant). If at least one ARBS was reported, then on average 1.15 sensations were reported (maximum 3).

On average, the intensity of the reported sensations for all body parts was 5.63 (min 3.00, max. 8.63), the pleasantness 5.33 (min. 3., max. 9.13), and it started 3.70 seconds (min. 0., max. 8.60) after starting focusing on the body part.

tingling	94
warmth	67
throb	44
tension	29
numbness	27
heaviness	27
pulse/heartbeat	23
pressure	22
coldness	21
pain	18
relaxation	18
a stabbing feeling	17
hunger	13
twitch	8

15. Table Frequency of types of attention related body sensations (ARBS) applying the ARBS-Test at first time point, summarizing the results of the 59 subjects of the test and the nine body part.

Only those types which were reported more than 5 times are presented in the table (out of the 531 possible occasions). Sensations reported 5 or less times were: itch, touch, pull, breath, light, cramp, squeeezing, narrowing, vibration, rest, tiredness, fullness, vertigo, heavy breath, deeper breath, radiation, weightless, growing, awareness of its presence, stroking, gloves, pinch, sweat, energy, airiness, touch of the ECG electrode, carressing, being bound up, tinnitus, sensitiveness, laziness, clatter, tickling, softness, muscle ache, rumble, discomfort (respectively).

During the ARBS-Test at the second measurement, across the 31 participants and 9 body parts, 38 different types of sensations were reported, out of which tingling was the most frequent type of sensation, warmth was the second, and throb was the third most frequent (

tingling	31
warmth	22
throb	18
pressure	13
tension	12
pain	10
relax	9
numbness	8
pulse/heartbeat	7
hunger	6

tingling	31
warmth	22
throb	18
pressure	13
tension	12
pain	10
relax	9

).

numbness	8
pulse/heartbeat	7
hunger	6

16. Table Frequency of types of attention related body sensations (ARBS) applying the ARBS-Test at second time point, summarized for the 31 subjects of the test and the nine body parts.

Only those types which were reported more than 5 times are presented in the table (out of the 279 possible occasion). Sensations reported 5 or less times were: a stabbing feeling, touch, pleasantness, pull, heaviness, coldness, twitch, itch, a squeezing feeling, a light (weight), gloves, vibration, rumble, bubbles, tiredness, being aware of its presence, caress, breath, tickling, heavy breath, insensitiveness, eyes twinkling, rooting, hardness, as if there would be an object on it, slowing breath, eyes are old, insects walking (respectively).

Most of the participants (23%) felt some kind of sensation at 8 places out of 9 (only 4 person felt nothing at any place, and 4 person felt something at all the 9 places). The most frequent place to feel something out of the 9 places (right palm, left palm, shoulders, nape and top of the head, face, belly, feet, chest, freely chosen part) was the freely chosen part: 81% of subjects reported ARBS here. Second most frequent body part was the right palm and face (65%), left palm and feet (61%), the least frequent place were the shoulders

(52%). At the freely chosen body part, the feet were picked most frequently (see **Error! Not a valid bookmark self-reference.**).

Table 17. Frequency of places of attention related body sensations (ARBS) at the point where participants choose freely a body part during the ARBS-Test

body part mentioned by participants	occurrence	first level category	second level category
thigh	3	26 (lower limbs)	40 (limbs)
knee	5		
calf	3		
feet	14		
leg	1		
shoulder	5	9 (arms)	
arm	3		
lower arms	1		
hand	3	5 (hands)	
fingers	2		
belly	5	11 (trunk)	21 (central parts)
chest	5		
waist, groin	1		
head	2	10 (head)	
forehead	2		
eyes	3		
ears	2		

Sometimes participant reported more than one sensation per body part. The average number of ARBS reported per body part was 0.67 (minimum:0, maximum: 1.4, reached by one participant), which is a lower frequency compared to the ARBS-Test answers at the first measurement. On average, the intensity of the reported sensations for all body parts was 5.47 (min 2.50, max. 7.75), the pleasantness 5.19 (min. 2.43, max. 9.22), and it started 3.45 seconds (min. 0., max. 6.50) after starting focusing on the body part.

Out of the participants who were interviewed about the cause of the ARBS (n= 38), 35 could give a guess about the cause. Most of them guessed that it was because of the attentional focus, or normal physiological processes (see 18). However, some of them gave other type of explanation, e.g. that (negative) thoughts, a disease, (bad) posture, experience with autogenic training, or being a goalkeeper and thus having a more sensitive palms might be the cause of the sensation.

At the second measurement, all the participants were interviewed about the cause of the ARBS, 39 could give a guess about the causes. Most of them guessed that it was caused by a current or past body posture or physical activity (see 18). Emotions, diseases, and processes of the digestive system were also frequent answers. The effect of past body-mind practice was also reported.

The main differences between the two measurements was that, at the first time, diseases or medical interventions, experience with a body-mind technique, and external causes were the three most often mentioned personal explanations, while at the second time, posture and recent physical activity, mental processes and emotions were the two most often mentioned explanations, while diseases and the therapies were only the third most frequent answer. Out of the participants who were interviewed about the effect of taking part in the ARBS-Test (n= 38), seventeen reported any kind of effect or change (see 19. Table). Most of the participants who gave an answer found it pleasant, calming, good. However, negative affect, novelty, and other effects were also reported.

18. Table Prevalence of the self-guessed origin, explanation or cause of the attention related body sensations (ARBS) as answered after the ARBS-Test in the first and second measurement.

First measurement			Second measurement		
Category	Example(s)	No. of cases	Category	Example(s)	No. of cases
Disease, curing intervention	'Genetic bone disease.' 'Dentological thing.' '3 years ago I kicked badly during football, which overstretched the knee ligament.'	15	Posture and physical activity	'I'm hanging on.' 'I was reading on the bus.' Yesterday I hunched a lot.'	13
Body-mind technique	'Yogic attention: to fill the body part with warmth automatically.' 'Autogenic training.' 'The same as in relaxation class, there it is automatic.'	10	Mental processes, emotions	'An intensive difficult period is over, I feel lightened.' Stress because of exams.	10
External	'Physical contact.' 'Narrow shoes'.	9	Disease, curing intervention	'A doctor examined me this morning.' 'I had a surgery in my nose, I'm allergic, and I am ill right now too.' 'I had a knee surgery ten years ago.'	8
Attention	'I looked with my eyes from the inside'. 'I paid more attention there.'	6	Hunger and digestion	'I'm digesting.' 'I'm hungry.' 'This week I had time only for sandwiches.'	7
Hunger	'It's been a while that I had lunch.'	6	Property	'I usually feel good.' 'My neck is always tense.'	7
Posture and physical activity	'Training without warming up.' 'It was platered up once.' 'Yesterday and today I walked a	6	External	'There was a cap on my head.' 'My watch constrained it.'	6

	lot, I inherited from my mother that I hurry a lot.'				
Mental processes, emotions	'Relative calmness.' 'It is a strange new place, disturbing.' 'One concrete psychic reason.'	5	Attention	'They were there, now I'm aware.' 'I payed more attention.'	5
Physiological	'Heart.' 'Circulation.'	3	Sleep (deprivation)	'I could not sleep well.'	4
Imagination	'Maybe I've just talked myself into it.'	2	Excuses	'I hurried to arrive here, it was difficult to focus inwards.'	4
Sleep (deprivation)	'Tiredness, I haven't slept too much'.	2	Body-mind technique	'I used to practice autogenic training, it is automatic.'	3
Excuses	'I was put off from alpha, it was hard to concentrate.'	2	Physiological	'If I pay attention to it, my heart is beating.'	2
Lifestyle and habits	'In my profession I pay attention a lot to my body and others body.'	1	Attention-brain-body loop	'Our brain commands partly to our circulation, so it becomes quicker at the place where I focus at.'	1
Substance usage	'Hangover'.	1	Spiritual	'Healing intention.'	1
Property	'It has been so for a long time'	1			
Dream	'I dreamed that I'm a famous person and when I exited the restaurant I was stabbed in the belly.'	1			
Memory	'As a kid, I was often tickled.'	1			

19. Table Prevalence of the self-perceived effect of paying attention to the body and scanning for attention related body sensations (ARBS) as answered after the ARBS-Test in the first measurement.

Category	Example(s)	Number of cases
Positive affect	'It was good to concentrate inwards.' 'I'm calmer.' 'Focusing inside makes me relaxed.'	11
Negative affect	'It depressed me.' 'It felt insecure, my body lives a life of its own.' 'I don't like it, I have high blood pressure.'	7
Novelty	'It is interesting, if I focus on it, it becomes stronger.' 'Surprising.'	5
Change in sensations	'I'm more hungry.'	2
Success	'I'm happy it came so quick.' 'It feels good that after decades of being a trainer I know my body.'	2
Other	'Ambivalent.'	1
Meaningful, message	'I feel tingling, as if I waited for something.'	1
Familiarity	'I know it well.'	1

At the second measurement, all the participants were interviewed about the effect of the ARBS-Test, and 29 reported any kind of effect or change. Most of the participants who

gave an answer found it pleasant, calming, good (see 20. Table). However, negative affect, novelty, and other effects were also reported.

One important difference between the two measurements, is that the self-perceived effect of body attention was mentioned as positive much often at the second time. Negative effects were prevalent similarly in the two cases.

20. Table Prevalence of the self-perceived effect of paying attention to the body and scanning for attention related body sensations (ARBS) as answered after the ARBS-Test in the second measurement.

Category	Example(s)	Number of cases
Positive affect	'Calming.' 'It is a feedback that I am lightened.' 'It calmed me, switched me off, I forgot my exams.'	18
Negative affect	'I was disturbed.' 'It was unpleasant, but now it is fine.' 'It was scary because it was quick and intensive.'	8
Other	'Sleepy.'	3
Novelty	'It is a strange experience that something appears if I pay attention to it. But it is pleasant.'	3
Meaningful, message	'It made me think.'	2
Change in sensations	'The muscle became relaxed.'	2
Decision	'I won't eat sandwiches anymore.' 'I have to get calmer.'	2
Success	'It was a success that I can really pay attention.'	1
Failure	'I tried to relax it with breath, it didn't work.'	1
Familiarity	'I get used to it.'	1

The descriptive characteristics of the further variables are shown in 21. Table.

21. Table Descriptive statistics (mean ± standard deviation) of personality dimensions, aspect of physical or body-mind activity.

Study		3 ’Longi’
Body awareness (BAQ)		83.4±12.55
Body awareness (SAS)		61.8±9.83
Somatosensory amplification (SSAS)		30.4±4.77
Perceived body symptoms (PHQ)		21.5±4.38
Body image dissatisfaction (BIQ)		5.7±1.53
Mindfulness (MAAS)		4±0.62
Body Responsiveness (BRQ)		4.6±0.71
	importance of interoceptive awareness	4.7±0.91
	perceived disconnectedness from the body	3.5±1.08
Positive affect (PANAS)		32.2±8.26
Negative affect (PANAS)		15.6±5.64
Ryan vitality		24.6±8.35
Spirituality (SCQ)		4±1.34
Absorption (TAS)		49±6.4
Big Five (BFI)		35.3±6.43
Physical activity		3.1±1.29
Experience with a body-mind technique		0.6±0.5
Weekly frequency of body-mind practice		0.5±1.23
Cardioceptive accuracy		0.5±0.28

4.3.2 Connection between ARBS and age, gender, personality and physical and body-mind activity

According to my correlational results (see 22. Table also), ARBS showed:

Hypothesis #1 a moderate positive connection with reporting ARBS during the real-life ARBS test.

Hypothesis #2 was a trait-like characteristic, showing a moderate temporal stability

Hypothesis #3 showed no correlation with age and gender,

showed a weak positive correlation with body awareness (see 4. Figure Histogram of body awareness for the participants who did not report ARBS (left) and for those who did (right).

Hypothesis #4 The histograms for the further variables are presented in the Supplementary materials.4. Figure),

Hypothesis #5 regarding the various subdimensions of (body) awareness, ARBS:

a. showed no connection with somatosensory amplification
b. nor with perceived body symptoms,
c. showed a very weak positive connection with body image dissatisfaction,
d. showed no connection with trait-like mindfulness,
e. nor with body responsiveness.

Hypothesis #6 Reporting ARBS showed no connection with positive and negative affect, nor with vitality.

Hypothesis #7 Regarding further personality traits, ARBS:

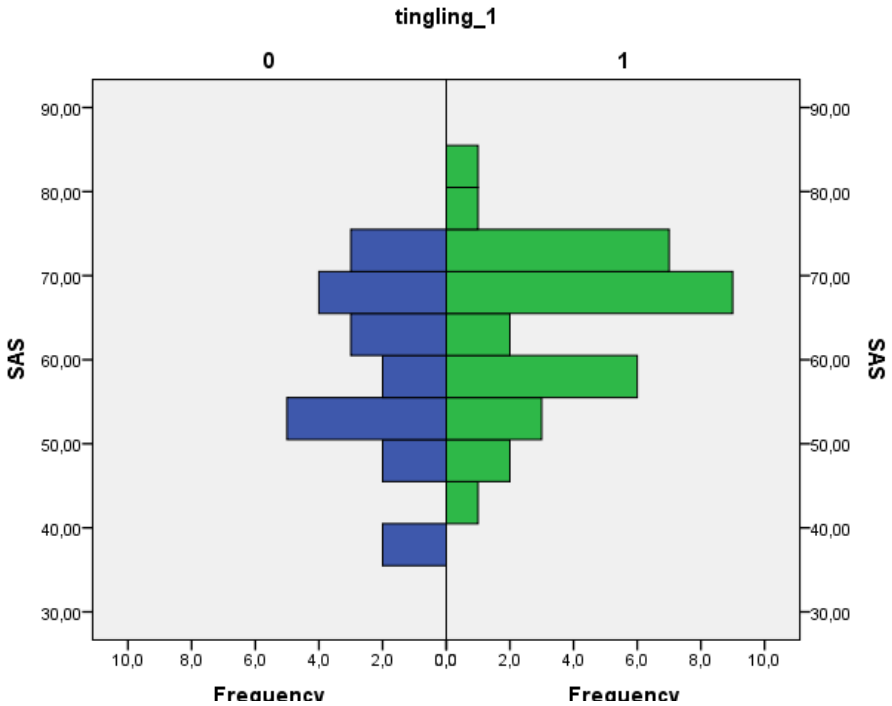
a. showed no positive connection with spirituality,
b. nor with absorption
c. nor with openness (factor of Big Five).

Hypothesis #8 Reporting an ARBS:

a. showed no positive connection with practice of sport and body-mind technique,

Hypothesis #9 reporting an ARBS on the ARBS-Qu showed no correlation with cardioceptive accuracy (i.e. heartbeat detection ability).

Hypothesis #10 ARBS-Test similar to ARBS-Qu showed a weak connection with body awareness, and as opposed to ARBS-Qu, it showed the expected significant connection with somatosensory amplification but did not show a significant connection with body image dissatisfaction.



4. Figure Histogram of body awareness for the participants who did not report ARBS (left) and for those who did (right).

The histograms for the further variables are presented in the Supplementary materials.

22. Table Spearman correlation between ARBS- and age, gender, personality body-mind practice and physical activity, cardioceptive accuracy.

After each Spearman correlation coefficients, the p-value and number of cases are given in brackets. Significance is signed in the same manner in the whole work: *: p = 0.01 to 0.05, **: p = 0.001 to 0.01, ***: p < 0.001. Numbers are bolded if they show a significant connection in the expected direction.

Study 3 'Longi'	ARBS-Qu	ARBS-Test
Age	.128 (.337, 58)	.142 (.28, 60)
Gender	-.143 (.284, 58)	.115 (.38, 60)
Body awareness (SAS)	**.209*** (.001 239)**	**.331** (.009, 49)**
Body awareness (BAQ)	**.388** (.002, 49)**	**,323** (.010, 49)**
Somatosensory amplification	**.**093 (.258, 49)	**,243* (.043, 49)**
Perceived body symptoms	.109 (.222, 50)	.161 (.129, 49)
Body image dissatisfaction	**.175* (.033, 49)**	.132 (.177, 49)
Mindfulness	.022 (.440, 49)	.118 (.204, 49)
Body responsiveness	-.020 (.444, 49)	.168 (.119, 49)
importance of interoceptive awareness	.083 (.281, 49)	.219 (.061, 49)
perceived disconnectedness from the	.132 (.178, 49)	.024 (.434, 49)
Trait positive affect	-.150 (.144, 50)	-.245 (.042, 49)
Trait negative affect	-.069 (.313, 50)	-.097 (.248, 49)
Vitality	-.038 (.394, 50)	-.176 (.109, 49)
Spirituality	-.160 (.130, 49)	-.039 (.394, 49)
Tellegen Absorption	-.049 (.367, 49)	-.195 (.085, 49)
Big Five - openness	-.251* (.037, 50)	-.178 (.106, 49)
Physical activity	.294 (.098, 19)	-.001 (.498, 17)
Experience with a body-mind technique	.161 (.118, 54)	.037 (.394, 53)
Frequency of body-mind practice	-.031 (.411, 54)	.082 (.277, 53)
Cardioceptive accuracy	-0.10 (.237, 55)	.020 (.441, 55)

4.3.3 The predictors of ARBS

The binary logistic regression analysis showed that the strongest predictor of ARBS-Qu was openness, and body awareness was also a significant independent predictor (see 23. Table). The strongest predictor of ARBS-Test was somatosensory amplification, and body awareness was not a significant independent predictor (see 24. Table).

23. Table Results of the logistic regression analysis predicting ARBS-Qu.
Numbers are bolded if they show a significant connection.

Nagelkerke R^2 = 0.44; p < 0.001	1st step		2nd step	
	Exp B	p	Exp B	p
Age	,857	,336	,997	,983
Gender	2,667	,148	**7,752**	,027
Body awareness	**1,075**	**,019**	**1,145**	**,005**
Body image dissatisfaction			,887	,640
Openness			**,782**	**,011**

24. Table Results of the logistic regression analysis predicting ARBS-Test.
Numbers are bolded if they show a significant connection.

Nagelkerke R^2 = 0.26; p < 0.001	1st step		2nd step	
	Exp B	p	Exp B	p
Age	1,117	,237	1,121	,187
Gender	1,528	,491	1,270	,713
Body awareness	**1,060**	**,044**	1,055	,067
Somatosensory amplification			**1,162**	**,034**

4.4 Discussion

The results of Study ‘Longi’ showed the ARBS is a trait-like characteristic which is moderately stable in time, and that the results of assessing it in a real-life experiment or in a written form are comparable.

Thanks to the phenomenological questions of ARBS-Test, one novelty of this study was to replicate the previous results of others (Michael & Naveteur, 2011), that tingling is the most frequent body sensation related to attention. Participants rated the pleasantness of ARBS as rather neutral (slightly pleasant on average). The personal explanations of ARBS and the self-perceived effect of body attention were two completely novel areas explored here for the first time. The ‘history of the body’, meaning the injuries, diseases, and the medical interventions were prominent explanations at the first and at the second measurements also. While experience with a body-mind technique and external causes were the two other most frequent explanations at the first measurement, at the second measurement emotions and recent body posture or physical activity became the other two most prevalent guess about the origin of ARBS. This might be because participants in the novelty of their first ARBST-test searched for well-known past situations, while at the second measurement they felt secure and familiar enough to concentrate on the here-and-now, and also to name emotions (which are usually suppressed, especially in a strange, novel situations).

Regarding two further novelties of this study, namely involving Tellegen absorption (i.e. the tendency to become deeply involved in an experience, especially in sensory or emotional ones) and Big Five openness (i.e. an imaginative, curious, and open-minded personality), the results did not support any positive connection with ARBS. The Absorption questionnaire rather grabs the exteroceptive aspect of experiences, which can be independent from the interoceptive dimension. The same explanation fits even more for the items of the Big Five openness, which do not mention the bodily dimension at all, and concentrate rather on artistic tendencies.

Body awareness showed the expected positive connection with ARBS-Qu, moreover, it was an independent predictor of ARBS-Qu. The link between body awareness and ARBS can be explained based on the Introduction (B. T. Tihanyi et al., 2018). The participants who reached higher scores on the questionnaire of body awareness might concentrate easier on the body, might be able to detect lighter sensations also (attentional disclosure), or tend more to activate central neuronal somatic representations (attention-evoked

model). Alternatively, participants with higher body awareness tend to initiate somatic self-regulation (e.g. relaxation) when focusing on the body, and these regulatory processes lead to changes in the peripheral tissues, causing a change in the body sensations.

However, body awareness was not the only, not even the strongest significant predictor of ARBS-Qu. The results with gender (being a female showed a strong positive predictive power) should be treated as an artifact, since gender did not present with a significant connection with ARBS in the correlational analysis, or in the first step of the logistic regression. But, the significant negative predictive power of Openness can not be explained in this way. This result is simply the opposite of my hypothesis, therefore it was quite difficult to find an explanation. Finally, I guess that the participants with low score on Openness might find it strange, disturbing, or stressful to bring attention to the body (and, moreover, close the eyes), and the negative arousal of this new situation might have caused somatic changes (e.g. higher heartrate, sweating, muscle tension, flush of warming), and thus they perceived an ARBS.

The negative arousal could be the explanation of the positive link between ARBS-Qu and body image dissatisfaction as well. The same negative arousal can stand behind the finding about the predictors of ARBS-Test. The significant positive power of body awareness vanished when somatosensory amplification was entered and became the only predictor. This seemingly contradicts the finding that the pleasantness of the ARBS during ARBS-Test was slightly above neutral. But in fact, it is possible that the somatosensory amplification predicted the unpleasant ARBS (which were also numerous), or alternatively, that the somatosensory amplifiers might amplify pleasant or neutral sensations as well.

The connections between ARBS and body awareness and body image dissatisfaction were weak statistically, which might be caused by the many situational factors (e.g. state affect, state arousal, state vigilance) that could influence ARBS-Qu. The same could explain the negative results regarding the connection between ARBS-Qu and other characteristics (e.g. somatosensory amplification, affect, sport and body-mind practice). It is also possible that the university students were less motivated in answering properly our questions (than the voluntary responders of our online questionnaire in the previous

two studies), and therefore they gave more superficial answers to the ARBS-Qu, which distorted our results.

This does not explain the lack of positive results with ARBS-Test, where participants reported many ARBS, and they appeared rather motivated in the lab to cooperate. Still, only body awareness and somatosensory amplification showed a connection with ARBS during the Test. (It is worth noting that the internal consistency of the Somatosensory Amplification Scale was poor in this sample, which could cause the negative result with ARBS-Qu, and questions the positive connections with ARBS-Test.) Here, the time (some days) passed between filling out the questionnaire and the real-life experiment might be an important distorter.

5. Study #4 ‘Students’

In this cross-sectional study, our main goal was to reveal the phenomenological aspects of ARBS through written form. As a secondary goal, we also wanted to check the hypothesis on a similar but bigger sample as in the previous Study ‘Longi’. Hence, our participants were university students again, studying at our faculty, and the nickname of this study became The ‘Students’ study.

A whole team worked on this research (see Acknowledgement also). I created the extended version of ARBS-Qu, processed the raw data, and the statistical analyses showed here were done by me.

5.1 Hypotheses and questions

My questions target the prevalence of ARBS in this sample, and the phenomenological details of ARBS (quality, intensity, pleasantness, quickness, self-guessed cause).

I hypothesized that results of ARBS-Qu

Hypothesis #1 will show no correlation with age and gender,

since the most recent study on this topic showed no connection between age and gender, and ARBS (Naveteur et al., 2015).

Hypothesis #2 will show positive correlation with body awareness,

as suggested by the attention-related models (Bauer, Barrios, et al., 2014; Beissner et al., 2015; Michael & Naveteur, 2011; Naveteur et al., 2015).

Hypothesis #3 will show positive correlation with various subdimension of (body) awareness, like:

a. somatosensory amplification (i.e. the tendency to label body sensations as unpleasant or harmful)

b. and perceived body symptoms,

since these constructs are thought to be connected to the tendency of somatization. The attention-disclosed model and the efferent model of tingling are the basis of this hypothesis: somatic amplifiers and body symptom perceivers might have stronger body attention, and also a higher

emotional activation converted to physiological arousal, which both fosters ARBS (Richard J. Brown et al., 2012; Rowlands, 2011).

c. body image dissatisfaction,

since it can foster body attention which discloses background sensations, moreover, in the experimental situation of body focus it can cause negative emotions and consequently autonomic arousal, which fosters ARBS.

d. trait-like mindfulness,

since the ability to concentrate on the present sensory experience might foster attention-disclosed sensations

e. body responsiveness (i.e. the tendency to treat the body as a relevant source of information in making decision, and treat the body as connected to the mind),

since someone with a suppressed and ignored body is less likely to be able to pay attention to it.

Hypothesis #4 Reporting ARBS will show positive correlation with affect and vitality,

Hypothesis #5 will show positive correlation with further personality traits:

a. spirituality

since spirituality means also an experience of deep connection or unity with the self (not just the universe or other humans e.g.)

(Fisher, 2010; Levine, 2008), which might come together with an openness towards the body, and an awareness of body sensations.

b. absorption (i.e. the tendency to get fully engaged in an experience, especially as an observer of an aesthetic moment),

since it might be associated with the ability to be absorbed in body experiences also

c. Openness (factor of Big Five),

since openness to previously unrecognized, or even weird body sensations during an ARBS experiment might foster experiencing an ARBS.

Hypothesis #6 Reporting an ARBS:

a. will show positive connection with the practice of a sport or a body-mind technique,

since having past experiences with such activities might have taught the individual how to pay attention to the body.

Hypothesis #7 I hypothesized that body awareness will show the strongest independent connection with ARBS, after controlling for somatosensory amplification, body image dissatisfaction, body responsiveness, mindfulness, spirituality, affect, practice of body-mind technique,

since body awareness is a general and neutral indicator of the tendency to focus on the body.

5.2 Methods

We collected data in the Spring and Autumn semesters of 2017. Overall, 94 participants took part in the study (age: 21.1±2.96, 42 female, 45 male), all participants were at or above the age of 18 years. Participants signed the informed consent before the measurements. They filled out the questionnaires on-line.

The study was approved by the Institutional Ethical Board of the Eötvös Loránd University.

5.2.1 Tools

Regarding the questionnaires, for the original Hungarian items and scoring, see **Error! eference source not found.**.

For the internal consistency values of every applied scale in this study, see 25. Table. All the scales showed acceptable or good or excellent internal consistency.

25. Table Cronbach's alpha values of the applied questionnaires for the 'Students' study.

Body Responsiveness Questionnaire subscales: importance of interoceptive awareness (IAw), perceived disconnectedness from the body (PD).

Body awareness (BAQ)	.83
Body awareness (SAS)	.83
Somatosensory amplification (SSAS)	.73
Perceived body symptoms (PHQ)	.76
Body image dissatisfaction (BIQ)	.81
Mindfulness (MAAS)	.86
Body Responsiveness (BRQ) (subscales: IAw, PD)	.71 (.81, 76)
Positive and negative affect (PANAS)	.83, .86
Ryan vitality	.93
Spirituality (SCQ)	.92
Big Five (BFI) - Openness	.70

5.2.1.1 *Attention related body sensation questionnaire (ARBS-Qu).* This second version of the ARBS questionnaire contains seven items. The first item is very similar to the previous 1-item ARBS-Qu, but now it avoids suggesting any concrete body sensation (tingling): 'Please, now concentrate on a freely chosen body part (e.g. hands, ears, thighs, etc.), with the eyes closed for 10-15 seconds. Has any sensation appeared at that body part while you were paying attention to it?' After the yes-no question, following items explore the quality of the sensation, the exact body part, the quickness of the sensation to emerge, the level of intensity and pleasure. The seventh item explores, additionally, the personal explanation of the cause of the sensation.

5.2.1.2 *Body Awareness Questionnaire (BAQ)*: see in Methods of Study #2 'Online', or in Supplementary materials.

5.2.1.3 The *Somatosensory Amplification Scale* (SSAS) see in Methods of Study #1 'Sports', or in Supplementary materials.

5.2.1.4 *Patient Health Questionnaire Somatic Symptom Severity Scale* (PHQ-15) see in Methods of Study #2 'Online', or in Supplementary materials.

5.2.1.5 *Mindful Attention and Awareness Scale (MAAS)* see in Methods of Study #2 'Online', or in Supplementary materials.

5.2.1.6 *Body Responsiveness Questionnaire (BRQ)* see in Methods of Study #2 'Online', or in Supplementary materials.

5.2.1.7 *Positive and Negative Affect Schedule* (PANAS) see in Methods of Study #1 'Sports', or in Supplementary materials.

5.2.1.8 *Vitality*: see in Methods of Study #2 'Online', or in Supplementary materials.

5.2.1.9 *Spiritual Connection Questionnaire* see in Methods of Study #3 'Longi', or in Supplementary materials.

5.2.1.10 *Tellegen Absorption Scale* see in Methods of Study #3 ‘Longi’, or in Supplementary materials.

5.2.1.11 *Big Five Inventory* (BFI) (Benet-Martínez & John, 1998; John, Donahue, & Kentle, 1991) measures the five broad dimensions (i.e., extraversion, agreeableness, conscientiousness, emotional stability, openness to experience) of personality. Here I used only the Openness subscale. The Hungarian version of the scale shows good psychometric properties, with a Cronbach's alpha coefficients 0.78 for openness to experience (Rózsa, Kő, Surányi, & Orosz, 2016).

5.2.1.12 *Sport and body-mind activity.* Sport activity was measured by the current number of hours spent with exercising per week. Participants answered if they had any experience with a body-mind method (defined as any kind of activity where body attention and inner concentration played a role, examples were autogenic training, relaxation, yoga, tai chi, meditation, contact dance), and if they practiced it also by the time of the study, they estimated the weekly frequency of the practice.

5.2.2 Statistical analysis

The first item of ARBS-Qu is one binary yes-no question, thus non-parametric correlations were used to examine the connection between the variables. The Spearman rho coefficients between these variables were then entered in a partial correlation analysis which controlled for the effect of age, gender (Conover, 1999). One-tailed correlational analyses were applied, since in all cases I had determined the expected direction of correlation in the hypotheses.

The independent connection between ARBS and the other variables was calculated using a binary logistic regression, with ARBS as criterion variable. Age and gender were entered as control variables in the first step. As for the predictors, the hypothesized strongest predictor, body awareness was entered in the first step, and then the other variables were entered in the second step, namely somatosensory amplification, body image dissatisfaction, physical symptoms, body responsiveness, mindfulness, spirituality, affect, openness, practice of sport and body-mind technique (those which did not show a significant connection in the previous correlational analyses were avoided). Since vitality and positive affect are strongly connected, positive affect was a priori chosen for this

regression analysis. Since body awareness was assessed with two constructs, the Body Awareness Questionnaire was a priori chosen for this regression analysis. The Somatic Absorption Scale was rejected in this case because it estimates the tendency to constantly monitor body posture and somatic events, while BAQ measures the tendency to perceive and predict somatic cycles, reactions, and change (Ferenc Köteles, 2014b).

Data analysis was conducted using the SPSS v.21 software.

The qualitative analysis of the self-guessed origin and perceived effect of ARBS followed several stages, as in accordance with the interpretative phenomenological analysis (J. A. Smith & Osborn, 2004), described in details at Study #3.

5.3 Results

5.3.1 Descriptive characteristics and statistics

Roughly half of the participants reported some kind of sensation when they answered the ARBS-Qu. (26. Table).

26. Table Prevalence of attention related body sensations (ARBS) applying the ARBS-Qu

Study 3 'Students'	
ARBS: no	41 (51%)
ARBS: yes	39 (49%)
total answers	80
missing	14

The most frequent type of ARBS was tingling (see

body part mentioned by participants	occurenc	first level category	second level category
little finger	4	10 (hands)	23 (limbs)
hand	6		
thigh	3	7 (legs)	
knee	3		

). The most frequent place of ARBS was the hand (mentioned in ten cases) (see Table).

On average, ARBS appeared roughly at the fourth second of attentional focus, they were rather not intensive and rather pleasant (see 30. Table).

calf	1		
biceps	2	5 (arms)	
arm	2		
lower arms	1		
limbs	1		
belly	2	3 (belly)	6 (trunk)
stomach	1		
chest	1	3 (trunk)	
back	1		
middle	1		
neck	1	3 (head and neck)	
head	1		
face	1		
whole body	3		
injury	1		
lateral ligaments	1		
muscles	1		

28.

27. Table Frequency of types of attention related body sensations (ARBS) applying the ARBS-Qu

sensation	occurence	%
tingling	11	11,7
warmth	7	7,5
throb	4	4,3
pulse	3	3,2
numbness	2	2,1
simply felt it	2	2,1
cold	2	2,1
pain	1	1,1
pressure	1	1,1
tiredness	1	1,1
sensitive	1	1,1
vibration	1	1,1
goosebumps	1	1,1
circulation	1	1,1
heavy	1	1,1

28. Table Frequency of places of attention related body sensations (ARBS) applying the ARBS-Qu

body part mentioned by participants	occurenc	first level category	second level category
little finger	4	10 (hands)	23 (limbs)
hand	6		
thigh	3	7 (legs)	
knee	3		
calf	1		
biceps	2	5 (arms)	
arm	2		
lower arms	1		
limbs	1		
belly	2	3 (belly)	6 (trunk)
stomach	1		
chest	1	3 (trunk)	
back	1		
middle	1		
neck	1	3 (head and neck)	
head	1		
face	1		
whole body	3		
injury	1		
lateral ligaments	1		
muscles	1		

Most of the participants who gave an explanation of the experienced ARBS guessed that it was because of the attentional focus, or normal physiological processes (see 29. Table). However, some of them gave other type of explanation, e.g. (negative) thoughts, a disease, (bad) posture, experience with autogenic training, or being a goalkeeper and thus having a more sensitive palms might be the cause of the sensation.

29. Table Prevalence of the self-guessed origin, explanation or cause of the attention related body sensations (ARBS) as answered in the ARBS-Qu

Category	Example(s)	Number of cases
Physiological	’Circulation of the blood.' 'Brain.' 'Nerves.' 'Heartbeat.'	7
Attention	’Directing the attention consciously to the subtle sensation.' 'I can concentrate well on bodily things.'	7
Posture and physical activity	’As a goalkeeper I use my hands very often, so I might be more sensitve at this body part.'	3
Attention-brain-body loop	’Because of the conecentration, the brain is focusing on the body parts, and the imagination becomes reality.'	1
Body-mind technique	’Well-practiced autogenic training.'	1
Disease, curing intervention	’I try to find it out also. Bad posture, nervous pressure, or maybe the symptom of some kind of autoimmune disease.'	1
External	’There is a soft breeze in the room due to the opened window.'	1
Thoughts	’Negative thoughts.'	1

The descriptive characteristics of the other variables are shown in 30. Table.

30. Table Descriptive statistics (mean ± standard deviation) of personality dimensions and body-mind activity.

Study		4 'Students'
ARBS: quickness (seconds)		3.9±1.96
ARBS: intensity (0-10)		4.0±1.55
ARBS: pleasantness (1-10)		5.9±1.49
Body awareness (BAQ)		86.5±13.39
Body awareness (SAS)		63.4±9.02
Somatosensory amplification (SSAS)		29.8±6.09
Perceived body symptoms (PHQ)		21.8±4.53
Body image dissatisfaction (BIQ)		5.9±1.7
Mindfulness (MAAS)		3.9±0.74
Body Responsiveness (BRQ)		4.8±0.77
	importance of interoceptive awareness	5±0.89
	perceived disconnectedness from the body	3.5±1.21
Positive affect (PANAS)		37.8±5.27
Negative affect (PANAS)		19±6.24
Ryan vitality		24.9±7.47
Spirituality (SCQ)		3.8±1.24
Absorption (TAS)		48.9±5.87
Big Five (BFI)		35±4.79
Hours spent with sport per week		9.8±14.07
Experience with a body-mind technique		0.6±0.49
Weekly frequency of body-mind practice		0.8±1.71

5.3.2 Connection between ARBS and age, gender, personality and physical and body-mind activity

According to my correlational results (see 31. Table also), ARBS showed:

Hypothesis #1 did not show correlation with age and gender,

Hypothesis #2 showed a weak positive correlation with body awareness measured with Body Awareness Questionnaire (see 5. Figure (while it did not show connection with the result of the other tool assessing body awareness, the Somatic Absorption Scale),

Hypothesis #3 regarding the various subdimension of (body) awareness:

a. somatosensory amplification was weakly connected with ARBS

b. perceived body symptoms,

a. body image dissatisfaction,

b. trait-like mindfulness did not show connection,

c. body responsiveness was not linked either, only its subscale, importance of body awareness showed a weak connection.

Hypothesis #4 Reporting ARBS showed no correlation with affect,

Hypothesis #5 Regarding further personality traits, ARBS showed:

a. no positive connection with spirituality,

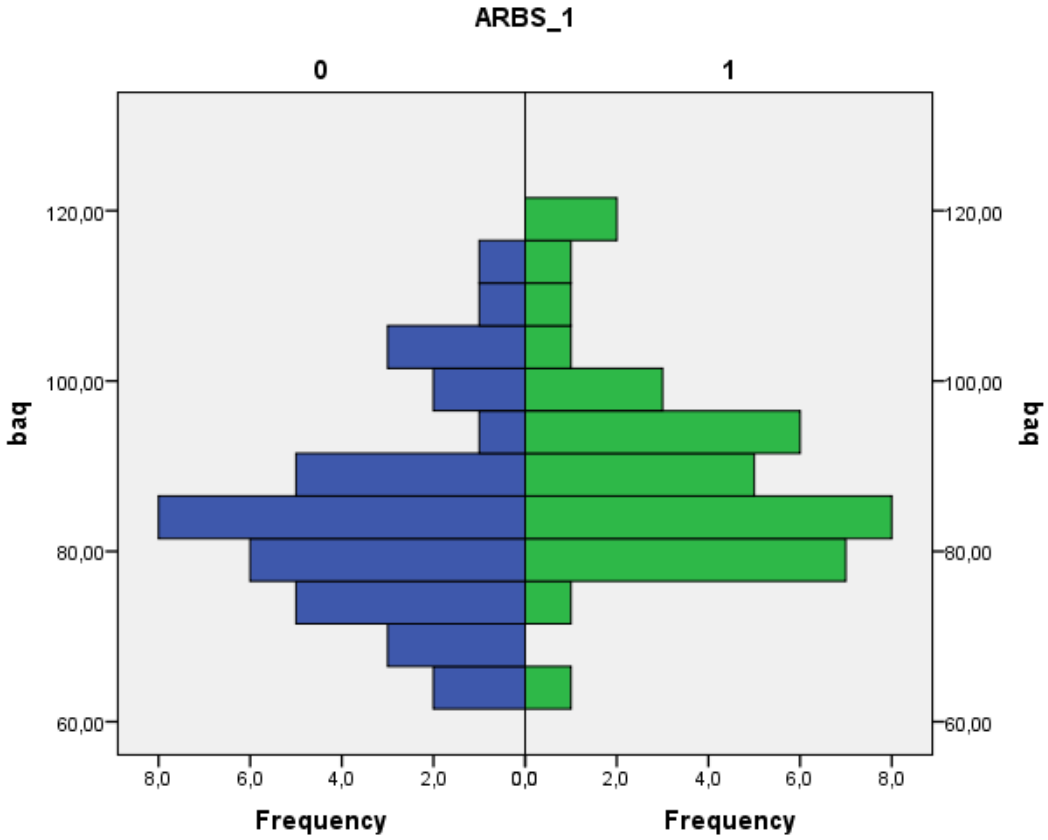
b. a moderate connection with absorption, but not in the expected positive direction

c. and no connection with openness (factor of Big Five).

Hypothesis #6 Reporting an ARBS:

c. showed no connection with practice of sport or body-mind technique.

5. Figure Histogram of body awareness for the participants who did not report ARBS (left) and for those who did (right). The histograms for the further variables are presented in the Supplementary materials.



31. Table Spearman correlation between ARBS- and age, gender, personality and physical activity.

After each Spearman correlation coefficients, the p-value and number of cases are given in brackets. Significance is signed in the same manner as in the whole work: *: p = 0.01 to 0.05, **: p = 0.001 to 0.01, ***: p < 0.001. Numbers are bolded if they show a significant connection in the expected direction.

Age	.041 (.733, 73)
Gender	-.072 (.545, 72)
Body awareness (measured by the Somatic Absorption scale)	.178 (.070, 68)
Body awareness (measured by the Body Awareness Questionnaire)	**.276** (.010, 68)**
Somatosensory amplification	**.214* (.037, 68)**
Perceived body symptoms	.150 (.108, 68)
Body image dissatisfaction	-.018 (.442, 68)
Mindfulness	-.060 (.314, 67)
Body responsiveness	.152 (.105, 68)
importance of interoceptive awareness	**.232* (.026, 68)**
perceived disconnectedness from the body	-.039 (.375, 68)
Trait positive affect	.071 (.280, 68)
Trait negative affect	.012 (.461, 68)
Vitality	.132 (.138, 68)
Spirituality	-.096 (.216, 67)
Tellegen Absorption	-.424*** (.000, 68)
Big Five - openness	.017 (.445, 68)
Hours spent with sport (per week)	.008 (.445, 68)
Experience with a body-mind technique	-.035 (.387, 68)
Frequency of body-mind practice	.157 (.167, 38)

5.3.3 The predictors of ARBS-Qu

The binary logistic regression analysis showed that the strongest predictor of ARBS-Qu was absorption in experience, and body awareness was a significant independent predictor only in the first step (see 32. Table).

32. Table Results of the logistic regression analysis predicting ARBS-Qu.
Numbers are bolded if they show a significant connection.

Nagelkerke $R^2 = 0.27$; $p < 0.001$	1st step		2nd step	
	Exp B	p	Exp B	p
Age	,941	,941	,828	,218
Gender	1,165	,757	,843	,755
Body awareness	**1,051**	**,014**	1,044	,131
Importance of body awareness			1,060	,867
Somatosensory amplification			1,012	,798
Absorption in experience			**,856**	**,006**

5.4 Discussion

Thanks to the new phenomenological questions of ARBS-Questionnaire, a novelty of this study was to show that exploring ARBS via online in a written form leads to similar results like exploring it in a real-life experiment. Namely, tingling is the most frequent sensation reported also in this written form, ARBS are rated as rather not intensive, and rather neutral (slightly pleasant on average). The qualitative question that assessed the personal explanation of ARBS let us know that most of the participants thought ARBS was the result of some physiological process (e.g. heartbeat) or the attentional focus, while some saw the role of a disease or past experience with a body-mind technique.

We found the expected positive connection between ARBS-Qu, and body awareness, somatosensory amplification, and the importance of body awareness. The latter finding

of the importance of body awareness suggests that the everyday tendency to listen to the body and to find body awareness useful is linked to the increased ability to focus on the body and perceive even the lighter body sensations.

Interestingly, when body awareness was measured by the Body Awareness Questionnaire then it showed a connection with ARBS, and not when it was measured by the Somatic Absorption Scale. Although the two tools has many similarities, the slight difference between them is that the Body Awareness Questionnaire measures the tendency to perceive and predict somatic cycles, reactions, and changes, while the Somatic Absorption Scale estimates the tendency to constantly monitor body posture and somatic events (Ferenc Köteles, 2014b). ARBS are rather based on non-proprioceptive (but viscероceptive) input, and the ability of perceiving is more important than the ability of constantly sustaining body attention, which could explain why ARBS is more closely linked to the former, Body Awareness Questionnaire.

Body awareness was a significant predictor of ARBS, but when Tellegen absorption (i.e. the tendency to become deeply involved in an experience, especially in sensory or emotional ones) was entered, it took away the role of the significant predictor from body awareness. Surprisingly, the direction of the connection between Absorption and ARBS was the opposite of the expected positive direction. How was this possible? A highly speculative explanation could be that for the participants with lower tendency to absorb into experiences and explore the 'artistic', aesthetic dimensions of perception the situation of answering the ARBS-Questionnaire was more strange, disturbing, or even stressful. The negative arousal caused by these negative emotions could cause either peripheral somatic changes (sensations of distress, like heartbeat, flush of warmth, sweating) or more alert awareness that detected ARBS more easily. On the other hand, the participants with higher score of absorption were more relaxed, and therefore they perceived 'nothing special'.

The connections were weak statistically, and since the data collection and the sample were similar to the previous studies, all the possible explanation of this statistical weakness were discussed there.

6. Study #5 ‘Physiology’

Parallelly to our (mainly) psychological work, we were also interested about the peripheral physiological concomitants of ARBS. The main question was: is there any measurable physiological change when someone reports perceiving a sensation in a body part? Therefore, this experimental study was completed in our physiology lab, and hence the nickname of this study became Study ‘Physiology’.

I took part in building the research plan and organizing the experimental appointments. The physiological measurements, digital processing, and all the statistical analyses showed here were done by me. The final paper was published by the title ‘Physiological and psychological correlates of attention related body sensations (tingling and warmth)’ in 2016 in the Physiology International (Impact Factor in 2016: 0.571) (B. T. Tihanyi et al., 2016).

6.1 Hypotheses and questions

ARBS are more frequent in resting condition (Michael & Naveteur, 2011), but they might be also fostered by aroused states, and changes in the autonomic tone (see Introduction). Therefor I wished to examine the different physiological characteristics of sympathetic tone (e.g. increased muscle tension and skin conduction), and parasympathetic tone (higher heart rate variability) without any expectations about the direction of the connections. In particular, warmth and

cooling are both frequent types of ARBS, therefore the local and core temperature were also examined.

Hence, I explored if the intensity of ARBS is linked to

Hypothesis #1 muscle tension,

Hypothesis #2 skin conduction,

Hypothesis #3 local temperature in the observed body area,

Hypothesis #4 core temperature

Hypothesis #5 heartrate variability.

6.2 Methods

6.2.1 Data collection

I collected data in the schoolyear of 2014/2015. Right-handed, healthy university students with no injury at the target locations (n = 27, 16 female, 11 male, age = 22.0±2.01 years) participated in the approximately 12 minutes 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 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), and the attentional sites were inked 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, see fig. 1. also) for 60 seconds each, in a randomized order. Attention periods were separated by 30 seconds long resting periods. The entire attention section was preceded by a 90 seconds long baseline period and followed by a 90 seconds 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

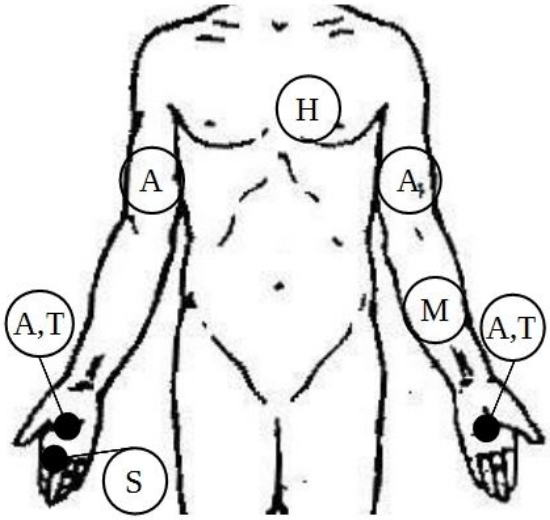
to each attention period, the audio guide asked the participants to direct their attention at the body part in question, and be aware of the sensations actually felt there.

The study was approved by the Research Ethics Board of the Faculty of Education and Psychology, Eötvös Loránd University. All participants signed an informed consent form before the experiment.

6.2.2 Tools

6.2.2.1 *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 a body sensation label (e.g. 'tingling' or 'warmth') only if that was the exact word used by the subject. Similar or related descriptors were treated separately. In the cases of not reporting a body sensation, we scored the intensity as '0'.

6.2.2.2 *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), heart rate variability (HRV, based on the. Root Mean Square of the Successive Differences values extracted from data of three channels: right and left clavicle, and iliac crest) were recorded continuously using the NEXUS-10 MKII (Mind-Media, NL) system (see 6. Figure also). Local temperature of the hand in focus was manually measured every 15 seconds using an infrared non-contact thermometer gun (model: DT-8806C) 0, 15, 30, 45 seconds after and right before the attentional instructions as well.



6. Figure: Sites of attentional focus and physiological measurements

A = attentional focus, T = local temperature measurement, M = electromyographic measurement, S = skin conductance measurement, H = electrocardiographic measurement

6.2.3 Data analysis

Physiological data obtained (electrodermal activity, electromyogram, electrocardiogram) was processed by the BioTrace+ software (V2014A UK). Mean values for the first 45 seconds of the attention and baseline periods were calculated, and then mean values were controlled by subtracting the mean value of the 45 seconds 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 seconds, 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 ρ) were used to estimate the relationships between attention related body sensations, and autonomic and somatomotor physiological processes. 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 physiologic variables and attention related sensations, the connections were investigated with two-tailed tests. In all cases, correlation values were controlled for gender using the procedure described by Conover and colleagues (Conover, 1999).

6.3 Results

6.3.1 Descriptive characteristics and statistics

In almost three fourth of the cases (27 participants, four body parts), an ARBS was reported. Tingling was experienced by 14 subjects (appr. 58% of participants; in total 24 times out of the 108 cases), and warmth was experienced by 10 subjects (appr. 42%; 21 times out of the 108 cases) (see 33. Table). Other sensations were apparent with such a low frequency that they could not be analyzed statistically. Therefore here we focused on the two most frequent sensations, tingling and warmth. The intensity of tingling and warmth was valued as ‘0’ when not these sensations were specifically reported, i.e. the intensity of tingling and warmth was ‘0’ in 84 and 87 cases (appr. 78% and 81% of total cases) respectively.

33. Table: Frequency of specific sensations during ARBS-test in Study 5 ’Physiology’. Percents are shown in brackets in total sensations with prevalence higher than one.

	Right palm	Left palm	Right arm	Left arm	Total
Tingling	6 (22.2%)	9 (33.3%)	3 (11.1%)	6 (22.2%)	24 (22.2%)
Warmth	7 (25.9%)	5 (18.5%)	5 (18.5%)	4 (14.8%)	21 (19.4%)
Numbness	3 (11.1%)	6 (22.2%)	2 (7.4%)	1 (3.7%)	12 (11.1%)
Heaviness	1 (3.7%)	1 (3.7%)	1 (3.7%)	2 (7.4%)	5 (4.6%)
Cold		1 (3.7%)	2 (7.4%)	2 (7.4%)	5 (4.6%)
Pulse			2 (7.4%)	1 (3.7%)	3 (2.8%)
Sting	1 (3.7%)	1 (3.7%)		1 (3.7%)	3 (2.8%)
Radiation	1 (3.7%)	1 (3.7%)	1 (3.7%)		3 (2.8%)
Throbbing	2 (7.4%)				2 (1.9%)
Calmness		1 (3.7%)	1 (3.7%)		2 (1.9%)
Pain			1 (3.7%)	1 (3.7%)	2 (1.9%)
As if being touched				2 (7.4%)	2 (1.9%)
Circulation		1 (3.7%)			1
Pressure			1 (3.7%)		1
A pleasant feeling		1 (3.7%)			1
Sparkling		1 (3.7%)			1
Twitch		1 (3.7%)			1
Tenseness				1 (3.7%)	1
Tiredness				1 (3.7%)	1
Simply felt the body	1 (3.7%)		1 (3.7%)	2 (7.4%)	4 (3.7%)
No sensation reported	9 (33.3%)	5 (18.5%)	8 (29.6%)	7 (25.9%)	29 (26.9%)
Tingling and warmth together	2 (7.4%)	2 (7.4%)	1 (3.7%)	2 (7.4%)	9 (8.3%)

The intensity of the sensations were also reported (34. Table). Due to the low number of cases, here I took into account also the cases of no sensation, with the intensity 0.

34. Table: Descriptive statistics for intensity of tingling and warmth sensation in Study 'Physiology'

	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

For the descriptive statistics of the physiological variables, see 35. Table.

35. Table Descriptive statistics (mean ± standard deviation) for the physiological variables in Study #5 'Physiology'.

	Right palm	Left palm
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

6.3.2 Connection between ARBS and physiological variables

The only significant correlation was with muscle tension measured during the period of focusing on the left forearm: it showed a significant moderate negative one with the intensity of perceived warmth in the left palm, but not with perceived tingling (**Error! Not a valid bookmark self-reference.**).

36. Table Spearman correlation between ARBS and concurring physiological changes.

After each Spearman correlation coefficients, the p-values are given in brackets. Significance is signed in the same manner as in the whole work: *: p = 0.01 to 0.05, **: p = 0.001 to 0.01, ***: p < 0.001. Numbers are bolded if they show a significant connection (the direction of connection was not expected here). Note: number of elements was 24 in all cases

	Tingling intensity in right palm	Warmth intensity in right palm	Tingling intensity in left palm	Warmth intensity in left palm
Muscle tension in left			-.113 (.584)	**-.499** (.009)**
Skin conductance in right	-.202 (.322)	.213 (.297)		
Local temperature (°C) in	.044 (.831)	**-.414* (.035)**	.104 (.614)	.082 (.691)
Core temperature (°C)	.060 (.385)	.231 (.128)	-.087 (.336)	.009 (.483)
Heart rate variability	-.073 (.725)	.120 (.559)	-.101 (.625)	-.050 (.807)

Skin conductance in the right palm showed no significant correlation with tingling or with warmth reported there. Local temperature measured in the right palm was not connected positively with tingling or with warmth reported there. Similarly, local temperature in the left palm was not related positively to tingling or warmth reported there. Finally, HRV measured during attention on the right palm was not connected with tingling or with warmth reported there, and HRV during attention on the left palm did not correlate with tingling or warmth reported there.

6.4 Discussion

In our study, attention related body sensations, more accurately, tingling and warmth, showed no connection with local (electrodermal activity and skin temperature) and systemic (heart rate variability) physiological changes. Attention related warmth sensation was connected to decreased muscle tension. Overall, this supports the hypothesis that attention related body sensations are generated mainly 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, itch) (Borg et al., 2015; Michael & Naveteur,

2011). In the Introduction, we proposed three alternative explanation for such frequent occurrence of body sensations in the absence of stimulation:

(1) attention-disclosed model: there is a constant background activity in the sensory neurons (caused by peripheral physiological fluctuations or ectopic neuronal activation),

(2) attention-evoked model: attention activates central interoceptive (somatosensory and visceroceptive) representations,

(3) efferent model: focusing on the body initiate thoughts, emotions or homeostatic regulation which changes peripheral physiology and activates sensory neurons.

The inverse connection between warmth sensation and muscle tension found here is in line with some previous results showing that attention related body sensations were blocked by movement (Beaudoin & Michael, 2014). It was suggested that the suppressive effect of muscle contraction on tingling and other body sensations might be mediated by top-down masking on the cortical and spinal levels (ibid), and by muscle afferents on the spinal level (Takazawa & MacDermott, 2010). It is also possible that the warm sensation helped our participants become aware of previously hidden muscle tension in this area and release it, although it seems contradictory that tingling did not have this effect. Additionally to this inverse connection between somatic sensations and muscle tension, since warmth has been 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 determined mainly by dermal circulation regulated by the sympathetic nerves (Johnson, Minson, & Kellogg, 2014) showed an inverse connection with the warmth sensation in the right palm, although increased circulation was thought to be linked to tingling and warmth (Peper & Holt, 2012). It is possible, that we detected the constant thermal fluctuation of the periphery (Pennebaker, 1982), and thus the participants in fact went through a warming period when they reported the sensation of warmth (arriving to the deepest point of their thermal curve and then starting to warm up), so the temporal average of temperature in this 1-minute long period was lower. It is also possible that this result appeared by chance, since it was statistically weak, and was not repeated at the other side of the body.

Skin conductance, an indicator of sympathetic activation, and heart rate variability, 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 paraesthesia (e.g. tingling) and hyperesthesia (mostly hyperalgesia) in some disorders, e.g. in fibromyalgia syndrome and complex regional pain syndrome (Martínez-Martínez, Mora, Vargas, Fuentes-Iniestra, & Martínez-Lavín, 2014), while parasympathetic activation was linked to the suppression of body sensations (mostly in the case of pain and itch) (Busch et al., 2013; Yosipovitch et al., 2003). 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 (Fogel, 2013). 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 one minute long periods using our methods.

We are aware of further limitations of this study and thus we recommend for future investigationsto involve also (1) the prior expectations of the subjects regarding body sensations caused by body attention; (2) the nervous system, either centrally (EEG, fMRI) or peripherally (ENG); (3) more detailed temporal (onset and endurance) and spatial (area and direction) characteristics of the subjective body sensations (4) state sleepiness and biorhythm, (5) effect of social desirability on reports, (6) longitudinal interventional design to explore the effect of learning a body-mind method.

7. General discussion: summarizing and comparing the five studies

7.1 Development of new tools

The perception of body sensations plays a basic role in the general affective state (‘common sense’), pain, symptoms (especially medically unexplained symptoms), but also emotions, and somatic self-regulation (of postural, or respiratory patterns), as well as sport and arts, body-mind practices (e.g. the ‘energy’ sensations) (B. T. Tihanyi et al., 2018). Interoception is sought to be assessed by many experimental tools and questionnaires (Mehling et al., 2009), and the different experimental methods lead to rather inconsistent results, since they tend not to correlate with each other, or body awareness questionnaires, or any other practically relevant phenomenon (Ferentzi et al., 2018). Self-rated questionnaires showed higher connection with clinical and practical variables, still, they are more distorted by the expectations and desires of the participants. Therefore, my goal in this thesis was to develop new tools which explore the momentary effect of turning the attention to the body, i.e. the experience that focusing on a body part reveals different body sensation (attention-related body sensations, ARBS), most frequently tingling. The fruits of this work of four different studies were two research tools: one is a questionnaire (ARBS-Qu), which can be applied on paper or digital form also, and the other is an experimental protocol (ARBS-Test), which was applied in a real-life setting.

The first version of the ARBS-Qu consisted of only one binary item, which registered if a participant perceived an ARBS while following the instructions (‘close the eyes’, ‘turn the attention to a body part’), or not. Later, we developed a 7-item version, which validated the previous 1-item version with a question that assessed the type of the experienced sensation. In most cases one of the typical ARBS (tingling, warmth, heartbeat) stood behind the ‘yes’ answers on the first item. Further questions of the 7-item ARBS-Qu reveal the perceived intensity, quickness, pleasantness of the ARBS, and also the personal explanation of the origin of the sensation.

ARBS-Test also had two versions: the first one was implemented for physiological measurement, therefore the attentional periods were long (60 seconds) and were separated by longer resting phases (30 seconds), in order to allow for the physiological changes to complete and vanish. The second version of the test was implemented to a solely phenomenological assessment. It consisted of guiding the participants’ attention to nine different body parts (15 seconds each), and after the attentional phase, it assessed in a

written form the perceived intensity, pleasantness, quickness of ARBS, and also the personal explanation of ARBS, and the perceived effect of paying attention to the body.
Regarding the application of the tools, ARBS-Qu can be easily built in any questionnaire kit, the 1-item version takes ca. one minute to answer, the 7-item version an additional one minute. The protocol for the experimenter to the ARBS-Test can also be easily learned, moderate concentration is needed during guiding the test, and the 9-body part version can be done in ca. 15 minutes. This can be shortened, by picking less body parts. I suggest for future researchers who wish to shorten the ARBS-Test to involve always (or only) the freely chosen body part, since that was the most frequent place to feel an ARBS at, and also this task is the closest to ARBS-Qu, since participants decide themselves where to focus in both cases. Moreover, ARBS-Test can be implemented in an online form, with audio or video instruction which guides the attention to the targeted body areas.
During the seven years of applying these tools, the participants understood easily the question and the task, no such feedback arrived that it is difficult to follow or to do the instructions. Moreover, Study #3 'Longi' let us explore the participants' experience while focusing the attention on the body by the guidance of the experimenter. Most of them stated that the ARBS-Test was a positive experience (calming, exciting), few of them perceived negative affect during the test (strange, disturbing), some of them found it simply surprising.

7.2 Phenomenological characteristics and scientific and subjective explanation of ARBS

According to the results of our four studies, roughly half of the participants (49-65%) reported an ARBS while answering the questionnaire. This is level of prevalence, although lower than observed in experimental tests (Michael & Naveteur, 2011), is comparable to previous results, which can be explained by supporting notions of a real life testing compared to filling out an online questionnaire, e.g. motivation to focus, expectations, suggestions given by the experimenter, arousal induced by the situation, and controlled elimination of distractive factors. Both at ARBS-Qu and ARBS-Test the meaning of a zero result should be investigated: it can mean literally no sensation, but it can also cover a sensation of 'it was simply there', or 'I felt it', and during these experiences a near-threshold sensation (tingling or warm) might have been sensed. Another question is when a subject reports having a sensation during ARBS-Test but this

is a transient intense negative sensation, like hunger, or acute pain caused by injury which would be reported by anyone. In this case, we do not know if the subject would have felt another sensation without/after this sensation. However, the low prevalence of such sensations in our research when we did explore the name of the sensation shows that intense negative sensations bring a low amount of error. The difference in prevalence of ARBS between the sample 'Sports' (35% reported ARBS, they were reached through teacher and centers) and the sample 'Students' (51% reported ARBS, they were asked to fill out the questionnaire by the teacher on the university, who was part of the researchers group) could be that the sport sample was less committed to the researcher and the research project.

The phenomenological questions included in ARBS-Qu in Study #4 'Students' and in ARBS-Test at first and second measurement in Study #3 'Longi' showed unanimously that the most frequent sensation was tingling, followed by warmth, and then throb, which is also in line with previous results on attention related sensations (Michael & Naveteur, 2011). It was a methodological question whether to count 'pulse' and 'heartbeat' together, and I decided to separate them because sometimes body attention causes rhythmic muscle contractions, pulses which are independent from heartbeat. I also separated 'circulation', because it can refer to the tingling sensation, attributed to circulation by the participant. 'Numbness' and 'fizzy' sensations might also be close to or identical with tingling, still, I decided to treat them separately. Few participants of ARBS-Test reported two sensations at the same time, but again, maybe in some cases even a weak but quicker sensation can mask a later sensation. Or, in the case of ARBS-Qu, there is only place for one sensation, and a second sensation can not be reported.

Eventually, what mechanisms can stand behind the ARBS explored by our tools?

As described in the Introduction chapter in details, there are four different mechanisms which potentially underlie the reported experiences (B. T. Tihanyi et al., 2018):

1. Afferent model: some of the participants might have suffered from a (neurological) disorder or a subclinical symptom (causing tingling or numbness), might have been suffering from local inflammation (causing throb and warmth)

or might have applied some (external) chemicals that had caused the sensation (warmth especially) and reported these feelings.

The Afferent model was not tested here, since participants were not asked about their detailed health status or the acutely applied chemicals at all, or not detailed and strictly enough.

2. Attention-disclosed model: when the ARBS-Qu (or test) made the participants concentrate on the body part, this opened the sensory gate for otherwise suppressed peripheral body sensations, which were caused by normal physiological processes or sensory neuronal background noise. As this information reached consciousness, they were perceived as a body sensation.
3. Attention-evoked model: It is possible that, even in the complete absence of sensory input, focusing attention on the body activated central neuronal representations.

   The positive results with body awareness (see later) supports the role of the two Attention-related processes. Our experimental settings did not let us to distinguish these two mechanisms. To achieve this, more advanced neurological tools (e.g. electroneurography) would be needed. The reported sensations are easy to interpret as signs of constantly ongoing physiological processes, e.g. throb (possibly caused by heartbeat in most of the cases), warmth (constant thermal fluctuation), and tingling (somatic sensory background noise).
4. Efferent model: maybe when the participants were asked to close their eyes and pay attention to their body, for some of them this situation evoked emotions (e.g. feeling disturbed, shameful, or excited, peaceful). Also, body attention could have initiated somatic self-regulation (correct poor posture, release unneeded muscle contractions, deepen breath). The emotions and the somatic self-regulatory processes could have led to peripheral physiological changes, perceived as a change in the body sensations. This could possibly happen unconsciously in some cases, without becoming aware of the fact that emotions or self-regulation have occurred.

   Although contradictory/controversial, we found connection between ARBS and affect (which, although was measured as a trait-like characteristic, might be linked to actual emotions) and that of practicing a body-mind technique (which

might be linked to the somatic self-regulatory abilities). This supports the role of the efferent mechanisms also.

5. Responder's bias: I can not exclude the possibility that some ARBS-report was based on lying, either because participants wanted to run through the questions, and quickly and randomly answered this question, or because they wanted to please the researchers and fulfill their perceived expectations. A phenomenon which is discussed here for the first time is the possible effect of the order of the questions on the respondents (Moore, 2002). In the questionnaire kits used here the ARBS-Qu tended to be among the first questions (after age and gender), because we thought that it is more vulnerable to the preload effect of the further body related questionnaires than the other way around. Still, ARBS-Qu could have preload the participants modifying the picture what they thought about their body, their connection with the body, etc.

The sensations came on average after 4 seconds of focusing the attention on the body, and they were mostly not intensive, and rather pleasurable, which are previously unexplored characteristics of ARBS. The quickness, intensity and pleasantness of the ARBS were comparable across the three measurements (see 37. Table). The time domain (3.5-4 seconds) of the appearance of the ARBS supports both the Attention-related and the Efferent models as explanations, since this slow occurrence gives enough time for emotional and autonomic processes to happen.

37. Table Descriptive statistics (mean ± standard deviation) of quickness, intensity and pleasantness of the ARBS

Study	3 'Longi' (1st)	3 'Longi' (2nd)	4 'Students'
ARBS: quickness (seconds)	3.7±1.79	3.5±1.61	3.9±1.96
ARBS: intensity (0-10)	5.6±1.51	5.5±1.36	4.0±1.55
ARBS: pleasantness (1-10)	5.3±1.21	5.2±1.43	5.9±1.49

The questionnaire version resulted in less intense and more pleasant sensations than the test version, which can be explained by the presence and constant guidance of the experimenter, which help to focus on the body, or even cause an arousal that facilitates

ARBS, but at the same time, it was disturbing for some participants (based on their feedbacks, for some it was highly disturbing to close the eyes and pay attention to the body in the presence of a stranger). The moderate pleasure is in contrast with conventional notions stating that conscious experiences emerging from the body are rather unpleasant and threatening (Ádám, 1998). My results showed that there can be a weak but positive affective effect of paying attention to the body. This is supported by a qualitative analysis of ARBS-Test answers, showing that many participants found it pleasant to focus the attention on the body. Pleasantness of a body sensation is influenced by higher-order processes, such as attribution and cognitive reaction (Pennebaker, 1982). Such processes are determined by situational factors, but trait-like variables, too. An example of such trait-like attitude which could influence these mental processes and thus should be involved in future ARBS-studies is self-compassion, i.e. the ability to stay mindfully present with experiences (even with unpleasant body sensations), and to remember that such difficult experiences are shared by and present in every human being (Neff, 2003). A participant with low self-compassion might get scared, angry or disappointed by the ARBS, increasing the intensity of negative ones, or alternatively, tend to ignore or suppress the body signs. On the contrary, high self-compassion might come together with understanding, accepting of the sensation, a readiness to self-care and self-regulate (Bakal, Coll, & Schaefer, 2008), and to 'savor' the positive sensations (Bryant & Veroff, 2007). In fact, our further results on the longitudinal and controlled effect of learning yoga as a beginner (Study #6 'Yoga', presented in my thesis for a Master's degree in recreation, (B. Tihanyi, 2019)) also suggested that there might be a connection between self-compassion and ARBS : ARBS-Qu showed a significant weak positive connection with self-compassion in the overall sample (n=90) before the yoga intervention, and this connection vanished after the yoga intervention (in the interventional group a tendentious weak positive connection remained, but not in the control group).

Regarding the participants' explanations of the ARBS, the online questionnaire form resulted in rather simple explanations (like ARBS was caused by 'attention', or physiological processes, like 'heartbeat', or the 'brain'), often answered in one word (see Study# 4 'Students'). Personally, I find these answers superficial, and I suspect that it was due to the lack of the personal presence of the experimenter, and to the environment of answering the questionnaire (which was completely uncontrolled). As opposing, the real-life meeting in the ARBS-Test resulted in more colorful, deep, complex answers

(involving personal history of the body, emotions) (see Study #3 ‘Longi’). The practice of a body-mind technique was present as an explanation in both studies, showing in these cases that some participants were trained in a way that turning the attention to the body was immediately linked to the application of a relaxing or meditative intervention, similar to a reflex.

7.3 Validity of ARBS tools: temporal stability and connection between ARBS and age, gender, personality, sport and body-mind activity, and other measures of interoception

7.3.1 Temporal stability of ARBS

The answers on ARBS-Qu and Test showed a temporal stability, which suggests that these tools are not merely subjects of acute, random circumstances and states, but they explore a relatively constant characteristic of the participants (see Study #3 ‘Longi’). The ARBS-Qu revealed more ARBS at the second time point than at the first one. There is the possibility that by applying the ARBS tools at the first measurement, we trained them to feel more ARBS in the second round. The presence of this learning-effect seems less probable in the light of the ARBS-Test: the number of ARBS decreased at the second measurement.

Theoretically, ARBS is connected to body attention, affective and somatic regulatory processes. To check these hypotheses, and thus explore the external validity of ARBS-Qu, we measured quite the same variables in the four psychological studies. For the comparison of these results, it is important to examine:

(1) the sample characteristics of the studies. Study #1 ‘Sports’ and #2 ‘Online’ involved large amount of adult responders, while Study #3 ‘Longi’ and #4 ‘Students’ smaller sample size of university students (see Supplementary materials), with ca. 10 years difference in age.

(2) the descriptive statistics of the examined variables. Regarding the mean and standard deviation values, all the examined values were comparable among the four studies (see Supplementary materials). This means, that the inconsistent

findings regarding the same variables through the four studies can not be explained by the different mean values across the samples.

7.3.2 Connection between ARBS and age and gender

Regarding age and gender, all the four studies showed unanimously that ARBS is independent from them (see 38. Table for all the correlational results mentioned here). This partly contradicts some mixed previous results, but is clearly in line with the most recent study on this topic (Naveteur et al., 2015). The results about age should be treated with care, since only adults were involved, Study #3 'Longi' and #4 'Students' involved only university students, but the deviation of age in the other two studies was not too wide either.

7.3.3 Connection between ARBS and body awareness

Regarding body awareness, all the four studies showed unanimously that ARBS is connected in a significant and positive way with it (see 38. Table). The connections with scores on either the Body Awareness Questionnaire or the Somatic Absorption Scale in the correlational analyses were weak or very weak.

In the case of somatic absorption in Study #4 'Students', the connection was unsignificant, which could have been caused by small sample size, or the slight difference between the the questionnaire measuring body awareness, namely that somatic absorption contains more proprioceptive dimensions, and also the ability to sustain body attention for longer periods (Ferenc Köteles, 2014b). This proves, that what ARBS-Qu explores partly overlaps with the self-reported and trait-like tendency to pay attention to the body signals and be aware of the somatic state.

Newer questionnaires explore the multidimensional structure of body awareness (Mehling et al., 2012). Our results in Study #6 'Yoga' suggested that ARBS-Qu is connected to a persons tendency to use the body for self-regulation (e.g. reduce distress through deep breath, muscle relaxation), to trust the body (to consider it as a relevant adviser in decision making), to notice the body (e.g. being aware of the lighter sensations), but not to the total score of the multidimensional body awareness inventory (B. Tihanyi, 2019). Moreover, the effect of the yoga intervention on the tendency to use the body for self-regulation was partially mediated by ARBS-Qu. Together with the present results,

and the weak connection between ARBS and unidimensional body awareness, this suggests, that the ARBS is connected to some but not all aspects of body awareness.

7.3.4 Connection between ARBS and somatosensory amplification

Regarding somatosensory amplification, all but Study #3 'Longi' showed unanimously a weak or very weak significant positive connection with ARBS. This connection suggests that what ARBS-Qu explores partly overlaps with the self-reported characteristics of finding the somatic sensations as intense and disturbing. The lack of connection in Study #3 'Longi' was possibly caused by the poor internal consistency of the scale in this sample.

The histograms of the frequency of somatosensory amplification in ARBS-responder and ARBS-negative subjects might suggest that in all the four samples the ARBS-responder participants had a high and a low somatosensory amplifiers subgroup, compared to the ARBS-negative participants (see Supplementary). Although this observation was not tested statistically, this would mean that being an ARBS-responder can be caused either by being a somatosensory amplifier (monitoring the body signals actively and searching for disturbing or scary sensations), or by being a somatosensory non-amplifier (e.g. being in peace with the body, and accept the sensations coming from it).

7.3.5 Connection between ARBS and body symptoms

Regarding perceived body symptoms, the three involved studies showed a very weak connection, and only one was significant. This incostistent finding could be explained by the smaller sample size in Study #3 'Longi' and #4 'Students'. Another explanation is that Study #2 'Online' was executed in a Spring semester, while the other two in a Spring plus an Autumn semester, and in Autumn, body symptoms might also be caused by external factors (e.g. flu). The results suggest that in these samples the symptoms reported on the questionnaire were rather independent from the attention-related mechanisms (and rather caused by peripheral biological processes), or that the experimental situation of the ARBS-Qu can not reproduce the real-life situation when a negative mental process is transformed into a body symptom. However, the histograms of the three studies suggest that a big subgroup of ARBS-responders showed a relatively low score on body symptoms, while the ARBS-negatives were distributed in a more even way. Even if this

observation was not tested statistically, it might suggest that some of the ARBS-responders had better abilities in somatic self-awareness and self-regulation.

7.3.6 Connection between ARBS and body image dissatisfaction

Regarding body image dissatisfaction, Study #2 ‘Online’ and #3 ‘Longi’ showed a very weak significant positive connection with it, and a very weak unsignificant negative connection. This weakly supports the hypothesis that those dissatisfied with their body image have stronger body attention (which discloses background sensations), or that in the experimental situation of body focus they feel negative emotions and the consequent autonomic arousal fosters ARBS. Is there any explanation for the missing significance in Study #4 ‘Students’? As I mentioned in the beginning of this section, there was no significant difference between the mean value of the variables in the four studies. This stands also for body image dissatisfaction, therefore an acceptable explanation for the lack of significance in Study #4 ‘Students’ is missing.

7.3.7 Connection between ARBS and mindfulness

Regarding mindfulness, all the four studies unanimously showed an unsignificant connection with ARBS. Some showed positive, and some showed negative connection, but all of them were statistically very weak. Although I hypothesized that the ability to concentrate on the present sensory experience might foster attention-related sensations, the results suggest the self-reported and trait-like mindfulness is independent from ARBS. It could be explained with the fact that this questionnaire measures the exteroceptive aspect of mindfulness, or that the ability to concentrate on the body during a short task is independent from the tendency to pay attention of the present sensory experiences instead of mind-wandering.

7.3.8 Connection between ARBS and body responsiveness

The results about the total score of the Body Responsiveness Questionnaire are also inconsistent, which can be explained with the fact that the Hungarian version’s two subdimensions were independent from each other (B. T. Tihanyi, Ferentzi, Daubenmier, et al., 2017).

Regarding the first subdimension, importance of interoceptive awareness, Study #2 ‘Online’ and #4 ‘Students’ showed the expected significant positive connections (weak and very weak though), while the very weak positive connection in Study #4 ‘Students’ was unsignificant. Since there is no known relevant difference between the sample in

Study #3 ‘Longi’ and #4 ‘Students’, the difference between their results might be caused by the relatively small sample size, which is more vulnerable to situational biases. On the other hand, the larger sample size in Study #2 ‘Online’ makes that significant result stronger.

Regarding the second subdimension, perceived body disconnectedness, all the three studies showed very weak connection with ARBS: furthermore, in Study #4 ‘Students’ this connection was in the expected negative direction, while in Study #2 ‘Online’ and #3 ‘Longi’ it was positive (the connection was significant only in Study #2 ‘Online’). Although I hypothesized that participants with a suppressed and ignored body are less likely to be able to pay attention to it and perceive ARBS, these results did not support that. Maybe the general tendency of perceiving the body as disconnected from the mind is not related to the ability of concentrating on the body in an experimental task. Or maybe in some cases the disconnectedness with the body causes body signals to be hidden during focusing on the body, in other cases asking a participant who thinks to be disconnected from the body to focus on the body causes an arousal, which is perceived in the form of ARBS.

7.3.9 Connection between ARBS and affect

Regarding the different aspects of affect (positive and negative affect, well-being, vitality), the results were highly inconsistent. All the connections with ARBS were very weak, some of them showed the expected positive direction, some of them the unexpected negative direction, and both direction had examples where the connection was significant. Therefore, although the studies could have suggested a connection here, when we take them together, it should rather be concluded that trait-affect is not connected to ARBS.

7.3.10 Connection between ARBS and spirituality

Spirituality showed the expected positive significant (although weak) connection with ARBS only in Study #2 ‘Online’, and on the contrary, a very weak and unsignifcant, unexpected negative connection in Study #3 ‘Longi’ and #4 ‘Students’. The mean value of the answers was exactly ‘4’ or close to it across the studies, which means in this scale ‘I can not decide’. However, the standard deviation was the highest in Study #2 ‘Online’. Maybe the participants of Study #2 ‘Online’ being older and more diverse (and of a bigger sample) showed more strongly the connection between spiritualty and ARBS, than the young university students, who tended to answer ‘I can not decide’ to more questions

about spirituality. It can be also argued, that the ability to listen to the body and perceive the lighter sensations is rather independent from the self-rated importance of spirituality.

7.3.11 Connection between ARBS and absorption and openness

Regarding Tellegen's absorption (i.e. the tendency to become deeply involved in an experience, especially in sensory or emotional ones) and Openness factor of the Big Five Inventory (i.e. an imaginative, curious, and open-minded personality), they showed a significant unexptected negative connection with ARBS in one of the studies (absorption a moderate one in Study #4 'Students', and openness a weak one in Study #3 'Longi'), while in the other study, they showed a very weak unsignificant connection (absorption a negative one in Study #3 'Longi', and openness a positive one in Study #4 'Students'). Because of the unusually strong (relative to the other connections in our studies) connection with absorption in Study #4 'Students', I tend to think that in Study #3 'Longi' the sample size was small enough to allow some outliers to destroy the statistical proof of the examined connection. As discussed in the chapter of Study #4 'Students', the unexpected negative connection could be speculated to be caused by the negative arousal accompanying focusing on the body for participants with low tendency to absorb into the experience. An alternative explanation is that Tellegen's absorption concentrates more on external stimuli and therefore there could be an inverse connection with immersing into the bodily sensations. The positive result about the connection between ARBS and openness was not that strong, therefore it is more probable that the significance was a random artifact.

7.3.12 Connection between ARBS and sport and body-mind practice

Unfortunately, the sport practice was assessed rather differently in the four studies, so the results are difficult to summarize. Most of them proved the lack of connection between ARBS and exercising, while Study #2 'Online' found an unexpected inverse connection with weekly sport frequency. As in all the correlational analyses, I checked the presence of the expected direction with a one-tail test, therefore this unexpected and very weak result could be treated as an artifact. Nevertheless, my initial hypotheses that sport might teach how to pay attention to the body, and being regularly engaged in sport might maintain a higher activation of the body with more vigorous body sensations have been rejected.

Regarding body-mind practice, only the binary responses about any experience with them showed a positive connection with ARBS and only in Study #2 'Online'. Maybe in the

other two samples of Study #3 ‘Longi’ and #4 ‘Students’ the university students could have some experience with body-mind techniques through eligible courses at their faculty, while the depth of the experience and the internal motivation could have been lower. Therefore the older and more experienced participants of Study #2 ‘Online’ could have deeper experiences with connecting the mind to the body, and therefor sensed ARBS more easily.

The connection between ARBS and practice of a body-mind technique is supported by the results of Study #6 ‘Yoga’ (B. Tihanyi, 2019). Here, ARBS-Qu showed an increase in the interventional yoga group from 1st to 2nd measurement, and did not decline significantly after the intervention, at 3rd measurement. At 2nd and 3rd measurements the scores of yoga group was significantly higher than the control group. The number of ARBS reported during the ARBS-Test also showed a significant increase during the yoga intervention, and the results of the yoga group was significantly higher than the results of the control group. It is probable, that such positive connection was hidden by the cross-sectional desing in the studies of this dissertation.

38. Table Spearman correlation between ARBS-Qu and variables that were measured in more than one study: age, gender, personality, sport and body-mind practice.

After each Spearman correlation coefficients, the p-value and number of cases are given in brackets. Significance is signed in the same manner as in the whole work: *: p = 0.01 to 0.05, **: p = 0.001 to 0.01, ***: p < 0.001. Numbers are bolded if they show a significant connection in the expected direction.

Study	1 'Sports'	2 'Online'	3 'Longi'	4 'Students'
Age	.010 (.735, 1179)	.053 (.412, 243)	.128 (.337, 58)	.041 (.733, 73)
Gender	-.021 (.479, 1179)	.095 (.137, 244)	-.143 (.284, 58)	-.072 (.545, 72)
Body awareness (SAS)	**.314*** (.000, 1170)**	**.209*** (.001 239)**	**.255* (.035, 49)**	.178 (.070, 68)
Body awareness (BAQ)		**.161** (.006, 238)**	**.388** (.002, 49)**	**.276** (.010, 68)**
Somatosensory amplification	**.152*** (.000, 1174)**	**.232*** (.000, 237)**	**.**093 (.258, 49)	**.214* (.037, 68)**
Perceived body symptoms		**.118* (.034, 238)**	.109 (.222, 50)	.150 (.108, 68)
Body image dissatisfaction		**.124* (.028, 238)**	**.175* (.033, 49)**	-.018 (.442, 68)
Mindfulness	.006 (.848, 1169)	-.092 (.078, 238)	.022 (.440, 49)	-.060 (.314, 67)
Body responsiveness		.034 (.301, 238)	-.020 (.444, 49)	.152 (.105, 68)
importance of interoceptive awareness		**.150* (.010, 238)**	.083 (.281, 49)	**.232* (.026, 68)**
perceived disconnectedness from the body		.107* (.049, 238)	.132 (.178, 49)	-.039 (.375, 68)
Trait positive affect	**.073* (.013, 1175)**	-.056 (.198, 238)	-.150 (.144, 50)	.071 (.280, 68)
Trait negative affect	.009 (.758, 1175)	**.134* (.019, 238)**	-.069 (.313, 50)	.012 (.461, 68)
Well-being	**.097** (.001, 1175)**	-.122* (.038, 238)		
Vitality		-.108* (.048, 238)	-.038 (.394, 50)	.132 (.138, 68)
Spirituality		**.268*** (.000, 238)**	-.160 (.130, 49)	-.096 (.216, 67)
Tellegen Absorption			-.049 (.367, 49)	-.424*** (.000, 68)
Big Five - openness			-.251* (.037, 50)	.017 (.445, 68)
Physical activity			.294 (.098, 19)	
Months of sport practice	.038 (.194, 1156)			

Frequency of sport practice	.028 (.332, 1167)	-.122* (.047, 186)		
Hours spent with sport (per week)				.008 (.445, 68)
Experience with a body-mind technique		**.156** (.008, 238)**	.161 (.118, 54)	-.035 (.387, 68)
Frequency of body-mind practice		.047 (.237, 238)	-.031 (.411, 54)	.157 (.167, 38)

7.3.13 The predictors of ARBS-Qu

My hypothesis that body awareness would be the strongest predictor of ARBS was supported only in Study #1 'Sports', while the other studies showed only a secondary predictive role (as in Study #3 'Longi') or no significant independent predictive role (as in Study #2 'Online' and #4 'Students') (see 39. Table). The pattern of the other significant predictors were completely inconsistent, and also difficult to explain by the known difference between the samples.

Based on this inconsistent pattern of predictors, and also remembering the moderate, weak, and very weak, and often inconsistent (and also unexpected) results of the correlational analyses, I should conclude that the external validity of ARBS-Qu is moderate or weak. In this form, it measures a momentary experience with the body, which is not highly connected to self-rated trait-like characteristics of the personality or physiological processes (see in Study #5 'Physiology'), and is not connected to other experimental measures of interoception (cardioceptive accuracy in Study #3 'Longi'). The ARBS-Test could have showed stronger connections with the hypothetically related variables, since it was measured in a controlled laboratory setting, with not only one but nine body parts brought in focus. But instead, it showed similarly weak or moderate connections.

39. Table Results of the logistic regression analysis predicting ARBS-Qu.

Only last (second) steps are showed. Numbers are bolded if they show a significant connection.

Study	1 'Sports'		2 'Online'		3 'Longi'		4 'Students'	
	Exp B	p	Exp B	p	Exp B	p	Exp B	p
Age	,992	,248	1,023	,103	,997	,983	,828	,218
Gender	,859	,289	,971	,947	**7,752**	**,027**	,843	,755
Body awareness (SAS)	**1,056**	**,000**						
Body awareness (BAQ)			1,369	,213	**1,145**	**,005**	1,044	,131
Somatosensory amplification	1,016	,216	1,041	,234			1,012	,798
Perceived body symptoms								
Body image dissatisfaction			1,137	,195	,887	,640		
Mindfulness			1,064	,810				
Body responsiveness								
importance of interoceptive awareness			,885	,479			1,060	,867
perceived disconnectedness from the body			,919	,579				
Trait positive affect	1,003	,905						
Trait negative affect			**1,850**	**,024**				
Well-being								
Vitality								
Spirituality			**1,480**	**,001**				
Tellegen Absorption							**,856**	**,006**

Big Five - openness					**,782**	**,011**		
Months of sport practice	1,001	,320						
Frequency of sport practice	,970	,298	**,847**	**,037**				
Body-mind technique			1,046	,904				

As repeated more times in this chapter, there are parallel mechanisms possibly underlying ARBS. One process is attention, linked to the ability to concentrate on the body, and perceive even the lighter sensations, coming from the border of 'something' and 'nothing'. Another process, however, is the emotional reaction given to this experimental setting, which instructs the participants to close the eyes and focus to the body. These reactions can evoke physiological changes, perceived as body sensations, and they can also change attention (enhance or inhibit it). Therefore, the same personality trait could hypothetically lead to opposing outcomes on an ARBS-Qu (or a Test). Namely, those who are familiar and accepting with the body, or have positive affect might perceive ARBS more easily (because they are open or positively aroused), but they might also feel nothing, since focusing on the body (for a short period) is an everyday experience for them. And those who are unfamiliar with the body, or have a negative affect might perceive ARBS harder (because it is difficult for them to truly turn to the body, or they are overwhelmed by their negative emotions), however, they might also perceive ARBS more easily (because they are negatively aroused by the question and instruction, or negatively aroused in general).

Besides the mixed quantitative results, this thesis also communicated qualitative results. Their interesting conclusion is that the simple action of paying attention to the body for an ARBS-Qu (or Test), (even remote) can evoke past somatic experiences (as if they were constantly 'there', waiting to pop-up), can reveal emotions, can support meaningful decisions, and can activate techniques from past body-mind practice (even unintentionally).

8. Conclusions

One thing that can be surely concluded is that the phenomenon of attention-related body sensations (ARBS) exists. When someone focuses the attention on the body, this can lead to the experience of some kind of sensations there, mostly tinging and warmth. Roughly half of our participants reported such sensations, typically after a few (3-4) seconds. The mechanisms behind this phenomenon are possibly: attentional processes, interoceptive background 'noise', emotional reactions and autonomic-somatomotor self-regulation. Although some of the contributors show huge temporal changes, ARBS was found to be temporally stable within subjects.

Again, despite the seemingly 'acute' nature of ARBS, some significant connection was found with trait-like mental characteristics, like body awareness. The presence of ARBS was similar to a two-sided coin. From one hand side, it seemed to be connected with somatosensory amplification (the tendency to find bodily signals as disturbing or dangerous) and frequency of perceived body symptoms. On the other hand, it seemed to be connected to the importance of interoceptive awareness (the tendency to support decision making with bodily intuition, and listen to the body). The cause and conscequence of the ARBS reported here could either be positive (e.g. loving the body and relaxing it), or negative (being scared of the body, and becoming tense by the task to pay attention to it), or neutral (simply turning the attention to ongoing bodily processes). This could contribute to the low statistical power of the results, and highlights the importance of the phenomenological exploration of ARBS, which can fill the gap between the mere phenomenon and standardized psychological questionnaires. In fact, the phenomenological analysis presented in this work revealed the width and colorfulness of the possible reactions and personal explanations given to ARBS. Maybe the biggest result of this dissertation is to provide tools to explore the phenomenon of ARBS, not only for face-to-face experimental designs, but also for online written settings. This can be important, since on a theoretical basis, ARBS can play a role in important health-related phenomena, such as medically unexplained symptoms, idiopathic environmental intolerance, nocebeo-effect, but also in placebo-effect, and the 'energy' experiences of body-mind techniques. This work forms the first step, creating and validating the questionnaire and the test for ARBS, and thus allows future researchers to explore this aspect of body-mind interactions.

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