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Theses of the Doctoral Dissertation

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Modalities and dimensions of interoception

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1. Introduction¹

1.1. Foreword

The term ‘interoception’ is not commonly used in the everyday language. Its significance, however, has been acknowledged from the very beginning of the history of scientific psychology (James, 1884; Lange, 1885). More recent theoretical and empirical accounts also support this view (e.g. Farb et al., 2015; Khalsa et al., 2018; Smith & Lane, 2015; Tsakiris & De Preester, 2018).

Interoception was defined in different ways in the past (Ceunen, Vlaeyen, & Van Diest, 2016). Recently, it has been described as “the body-brain axis of signals originating from the internal body” (Manos Tsakiris & De Preester, 2018, p. v). Leaving aside the question of terminology, there are several methodological issues to discuss, namely how interoceptive modalities and dimensions relate to each other. The main topic of this recent doctoral dissertation is what the multimodal and multidimensional approach tells us about the nature of interoception.

1.2. The structure of the dissertation

The structure of my publication based dissertation is as follows. In the *Introduction*, my aim is to provide the reader with an overview of the current scientific knowledge of interoception, focusing especially on interoceptive modalities and dimensions. Accordingly, I introduce and describe various interoceptive modalities (i.e. internal sensory channels), and also list several factors that might influence the assessment of interoceptive accuracy. Following that, multichannel investigations are introduced briefly. After discussing the modalities of interoceptive accuracy, I introduce another important dimension of interoception, namely interoceptive sensibility, measured with self-rating. Firstly, I list several related questionnaires; and secondly, provide an overview about the relation of the two main

1 Introduction is based on the translated and edited parts of the following papers:

Ferentzi, E., & Köteles, F. (2016). A szívdobogás percepciójának kapcsolata különböző patológiákkal [The relationship of heartbeat perception with different pathologies]. In S. Csibi & M. Csibi (Eds.), *Aktuális kérdések és alkalmazások az orvosi pszichológia területéről [Current topics and methods in medical psychology]* (pp. 145–162). Kolozsvár: Ábel Kiadó;

Ferentzi, E., Tihanyi, B. T., Szemerszky, R., Dömötör, Z., György, B., & Ferenc, K. (2018). Interocepció. Narratív összefoglaló [Interoception. Narrative review]. *Mentálhigiéne És Pszichoszomatika*, 19(4), 297–334. <https://doi.org/10.1556/0406.19.2018.014>

interoceptive dimensions, accuracy and sensitivity. I also discuss the relation of interoception to health, namely what might be the advantages and disadvantages of a certain level interoception. Additionally, I introduce a model of information processing (i.e. predictive coding) that might be able to explain how interoceptive information is integrated and evaluated. Last, but not least, I summarize the aim of the dissertation.

Following the *Introduction*, I introduce the four empirical studies my doctoral thesis based upon. Study 1 (Chapter 2; Ferentzi, Drew, Tihanyi, & Köteles, 2018) investigates the longitudinal associations between two interoceptive dimensions, namely interoceptive accuracy (assessed with the heartbeat perception task by Schandry; Schandry, 1981) and sensibility (assessed with the Body Awareness Questionnaire; Köteles, 2014; Shields et al., 1989). Study 2 (Ch.3; Ferentzi et al., 2017) focuses on four interoceptive modalities, namely heartbeat perception, balancing ability, and the perception of pain and bitterness. This paper also included self-report variables such as interoceptive sensibility, somatosensory amplification and the Big Five personality factors. Study 3 (Ch.4; Ferentzi, Bogdány, et al., 2018) also focuses on the interoceptive modalities in an independent sample, and includes two additional sensory modalities, namely gastric sensitivity (assessed with the water load test) and two tasks measuring the proprioceptive sensitivity of the elbow joint. Finally, Study 4 (Ch.5; Ferentzi, Horváth, & Köteles, 2019) investigates the association between heartbeat perception, gastric sensitivity, proprioceptive sensitivity and subjective well-being.

The *General discussion* of my PhD dissertation provides a brief summary of the findings of the four introduced empirical studies, and aims to connect the recent findings to the existing literature. The discussion continues with an overview of the limitations of the four presented papers, which is followed by some suggestions for future studies. The dissertation ends with a brief conclusion.

1.3. Background and aims of the dissertation

The aim of this doctoral dissertation is to investigate some of the key issues related to interoception, namely its temporal stability, the relation between interoceptive dimensions and modalities, and their connection to health and illness-related psychological constructs.

1.3.1. The relation of interoceptive sensibility and interoceptive accuracy

The first topic of my thesis is the relation of the two main dimensions of interoception, namely self-rated interoceptive sensibility and interoceptive accuracy assessed with a sensory task. This is in the focus of Study 1. (Ch.2; Ferentzi, Drew, et al., 2018). Interoceptive sensibility and accuracy do not relate to each other according to the majority of the literature (e.g. Ainley & Tsakiris, 2013; Garfinkel, Seth, et al., 2015; Khalsa et al., 2008). Although this problem has been recognized much earlier (McFarland, 1975; Whitehead, Drescher, Heiman, & Blackwell, 1977), the necessary conceptual clarifications have started only quite recently (Ceunen, Van Diest, & Vlaeyen, 2013; Garfinkel & Critchley, 2013). It is important to point out, however, that the conclusion of independence is based on cross-sectional studies, which do not take possible spontaneous fluctuations into account. Additionally, the temporal stability of the two constructs has been investigated mainly in studies with a focus of developing various aspects of interoception (e.g. Khalsa et al., 2008; Nielsen & Kaszniak, 2006; Parkin et al., 2013). Even if only the control group is taken into account, this design might lead to different results as a longitudinal study designed to investigate temporal stability that is not influenced by any intervention.

1.3.2. The relation of interoceptive modalities

The second topic that my thesis aims to investigate is the relation of various interoceptive modalities. This will be the focus of Studies No. 2 and 3 (Ch.3-4; Ferentzi, Bogdány, et al., 2018; Ferentzi et al., 2017). Interoceptive accuracy has various modalities or interoceptive channels. According to the majority of the studies (with some exceptions, e.g. Herbert et al., 2012; Whitehead & Drescher, 1980), these interoceptive modalities are not associated with each other with respect to perception accuracy. The number of the papers focusing on this topic, however, is limited; just like the number of the investigated interoceptive channels (e.g. Herbert et al., 2012; Steptoe & Noll, 1997).

1.3.3. The relation of interoception to health and illness

The third topic of my thesis is the investigation of the correlates of interoception, those that are (directly or indirectly) related to health and illness. In the literature, both the negative and positive consequences of high interoceptive ability are emphasized (e.g. Aronson, Barrett, & Quigley, 2006; Barsky, 1979; Farb et al., 2015; Farb & Logie, 2018). It is particularly interesting to investigate this topic from a multidimensional and multimodal perspective. Study 2 (Ch.3; Ferentzi et al., 2017) involves somatosensory amplification, while Study 4, (Ch.5; Ferentzi et al., 2019) investigates subjective well-being. In both studies, interoception is investigated both with self-rated measures and sensory assessment (multidimensionality), and interoception itself is also grasped by multiple assessments (multimodality).

1.4. A note on the applied terminology

Before the introduction of the four empirical studies, I would like to highlight some terminological inconsistencies of the literature, and especially how this dissertation deals with them.

In this doctoral dissertation, the sensory aspect of interoception is systematically called 'interoceptive accuracy' or 'interoceptive sensitivity' (Study 1-3.; Ferentzi, Bogdány, et al., 2018; Ferentzi, Drew, Tihanyi, & Köteles, 2018; Ferentzi et al., 2017). In Study 4 (Ferentzi et al., 2019), however, only the term 'interoceptive accuracy' has been used.

The description of the self-rated measure assessed with questionnaires is 'interoceptive awareness' or 'interoceptive sensibility' in Study 1-3 (Ferentzi, Bogdány, et al., 2018; Ferentzi, Drew, et al., 2018; Ferentzi et al., 2017). The construct is named 'interoceptive sensibility' in Study 4 (Ferentzi et al., 2019). Table 1 provides a summary the applied terminology.

The inconsistency of the applied terminology of the dissertation reflects well the fact that there is no consensus in the literature regarding the terms: we changed the terminology under the pressure of the reviewers of our papers, as they insisted to follow the terminology of certain papers. This was particularly prominent in the case of the Body Awareness Questionnaire (and the assessed construct, body awareness), more precisely whether it can be interpreted as an assessment of interoception.

Table 1. Terms used for the main dimensions of interoception in this dissertation

Chapters of the dissertation	Assessed with sensory measures	Measured with self-rated questionnaires	Note
Study 1 (Ch.2)	interoceptive accuracy or sensitivity	interoceptive awareness or sensibility	BAQ is considered as the measure of body awareness
Study 2 (Ch.3)	interoceptive accuracy or sensitivity	<i>not applicable</i>	BAQ is considered as the measure of body awareness
Study 3 (Ch.4)	interoceptive accuracy or sensitivity	interoceptive awareness or sensibility	<i>not applicable</i>
Study 4 (Ch.5)	interoceptive accuracy	interoceptive sensibility	BAQ is considered as the measure of interoception
Introduction and Discussion (Ch.1 and Ch.6)	interoceptive accuracy	interoceptive sensibility	BAQ is considered as the measure of interoception

Note: Ch – chapter; BAQ: Body Awareness Questionnaire

The reader has to keep these inconsistencies of the terminology in mind not only when looking at the following empirical studies, but also when reading any other papers on interoception.

2. Interoceptive accuracy and body awareness – Temporal and longitudinal associations in a non-clinical sample (STUDY 1)²

2.1. Background and aims

Various aspects of interoception are regarded as temporally stable phenomena. This study aims to investigate the temporal stability of and longitudinal associations between interoceptive accuracy (as measured with mental heartbeat tracking task) and a related concept, body awareness (assessed by self-report).

2.2. Methods

In a two-month longitudinal study 103 university students (31% male, 23.34 ± 4.34 yrs.; 44 Hungarians; 36.4% male, 21.4 ± 1.67 yrs. and 59 Norwegians; 25.4% male, 24.8 ± 5.09 yrs) were investigated using Schandry's heartbeat tracking task (Schandry, 1981) and the Body Awareness Questionnaire (Köteles, 2014; Shields et al., 1989). The language used (questionnaire and instructions) was Hungarian for the Hungarians, and English for the Norwegians.

2.3. Brief summary of the results

Both interoceptive accuracy and body awareness showed good test-retest reliability ($r = 0.60$ and $r = 0.73$, respectively; $p < 0.001$ in both cases). The two concepts were independent of each other at baseline ($r = 0.06$, $p = 0.587$), and did not predict each other over an eight weeks period of time.

2.4. Discussion

Self-reported body awareness and objectively measured interoceptive accuracy are temporally stable and not related to each other.

2 Chapter 2. is based on the following paper: Ferentzi, E., Drew, R., Tihanyi, B. T., & Köteles, F. (2018). Interoceptive accuracy and body awareness – Temporal and longitudinal associations in a non-clinical sample. *Physiology & Behavior*, *184*(Supplement C), 100–107. <https://doi.org/10.1016/j.physbeh.2017.11.015>

3. What makes sense in our body? Personality and sensory correlates of body awareness and somatosensory amplification (STUDY 2)³

3.1. Background and aims

The associations of body awareness and somatosensory amplification with the Big Five personality factors and sensory modalities were investigated in a cross-sectional study. It was expected that both constructs would be related to introversion; and that somatosensory amplification as opposed to body awareness would be connected with emotional lability. Perception of pain and bitter taste were expected to be associated with both body awareness and somatosensory amplification; whereas heartbeat perception and balancing ability were not.

3.2. Methods

A sample of university students ($n = 212$, 45.3% male, age: 22.2 ± 2.76 years) filled out questionnaires assessing body awareness (Shields et al., 1989), somatosensory amplification (Barsky, Wyshak, & Klerman, 1990; Köteles et al., 2009), and the Big Five (Benet-Martínez & John, 1998; Rózsa, Kő, Surányi, & Orosz, 2016), and a subsample of participants ($n = 118$, 44.1% male, 21.2 ± 1.39 years) completed the sensory measurements (heart rate detection, balance, perception of pain and bitterness).

3.3. Brief summary of the results

Somatosensory amplification showed a weak connection with emotional lability and introversion, while body awareness was associated with openness and conscientiousness. Furthermore, somatosensory amplification was related to the perception of pain and bitter taste, whereas body awareness was not related to any interoceptive modality. No correlations among the perceptions of different sensory modalities were found.

3 Chapter 3. is based on the following paper: Ferentzi, E., Köteles, F., Csala, B., Drew, R., Tihanyi, B. T., Pulay-Kottlár, G., & Doering, B. K. (2017). What makes sense in our body? Personality and sensory correlates of body awareness and somatosensory amplification. *Personality and Individual Differences*, 104, 75–81. <https://doi.org/10.1016/j.paid.2016.07.034>

3.4. Discussion

Body awareness and somatosensory amplification are related but not identical constructs; while interoceptive ability cannot be generalized across the modalities interoceptive accuracy.

4. Multichannel investigation of interoception: Sensitivity is not a generalizable feature (STUDY 3)⁴

4.1. Background and aims

In empirical studies, interoception is usually assessed using heartbeat detection (Whitehead et al., 1977) or tracking tasks (Schandry, 1981), often with the implicit assumption that cardioception reflects general interoceptive ability. Studies that applied a multichannel approach measured only a limited number of modalities (e.g. Herbert et al., 2012; Steptoe & Noll, 1997; Whitehead & Drescher, 1980). In the current study, six modalities were assessed to gain a deeper understanding of the relationship between the different sensory channels of interoception.

4.2. Methods

142 university students participated in the study (54% male; age: 21.93 ± 3.582). Individuals with missing data for more than two tasks out of the six were excluded ($N = 24$; final sample: $N = 118$, 53% male; age: 21.72 ± 3.007). In the present study, six different interoceptive modalities were investigated, which were the followings: gastric perception (modified version of the water load test, Boeckxstaens, Hirsch, Van Den Elzen, Heisterkamp, & Tytgat, 2001), heartbeat perception (Schandry task, Schandry, 1981), proprioception (reproduction of the angle of the elbow joint; used the modified version of the device of Goble, 2010), ischemic pain (tourniquet technique, (Amanzio & Benedetti, 1999)), balancing ability (one leg stand), and perception of bitter taste (see also: Ferentzi et al., 2017) were measured. Pair-wise

4 Chapter 4. is based on the following paper: Ferentzi, E., Bogdány, T., Szabolcs, Z., Csala, B., Horváth, Á., & Köteles, F. (2018). Multichannel investigation of interoception: Sensitivity is not a generalizable feature. *Frontiers in Human Neuroscience*, 12. <https://doi.org/10.3389/fnhum.2018.00223>

correlation analysis and exploratory factor analyses (principal component analysis and maximum likelihood extraction with oblimin rotation) were then carried out with a three-factor solution to investigate the underlying associations.

4.3. Brief summary of the results

Correlation analysis revealed significant associations only between variables belonging to the same sensory modality (gastric perception, pain, bitter taste). Similarly, the three factors that consistently emerged in the factor analyses represented the three aforementioned modalities.

4.4. Discussion

Interoceptive sensitivity assessed by using one channel only cannot be generalized. Interoceptive modalities carrying crucial information for survival are not integrated with other channels.

5. Do body related sensations make feel us better?

Subjective well-being is associated only with the subjective aspect of interoception (STUDY 4)⁵

5.1. Background and aims

According to the proposition of several theoretical accounts, the perception of the bodily cues, interoceptive accuracy and interoceptive sensibility, has a significant positive impact on subjective well-being. Others assume a negative association; however, empirical evidence is scarce.

5.2. Methods

5 Chapter 5. is based on the following paper: [Ferentzi, E., Horváth, Á., & Köteles, F. \(2019\). Do body-related sensations make feel us better? Subjective well-being is associated only with the subjective aspect of interoception. *Psychophysiology*, 56\(4\), e13319. <https://doi.org/10.1111/psyp.13319>](#)

In this study, 142 university students (53,5% male, age: 21.93 ± 3.582 years) completed questionnaires assessing subjective well-being (Bech, Gudex, & Johansen, 1996), interoceptive sensibility (Shields et al., 1989), and subjective somatic symptoms (Kroenke, Spitzer, & Williams, 2002). They also participated in measurements of proprioceptive accuracy (reproduction of the angle of the elbow joint; used the modified version of the device of Goble, 2010), gastric sensitivity (modified version of the water load test, Boeckxstaens et al., 2001), and heartbeat tracking ability (Schandry task, Schandry, 1981).

The investigation was part of a broader study on interoception (see above, Study 3). The overlapping variables between the two investigated data sets are the three measures of interoceptive accuracy.

5.3. Brief summary of the results

Subjective well-being showed weak to medium positive associations with interoceptive sensibility and weak negative associations with symptom reports. No associations with measures of interoceptive accuracy were found. Gastric sensitivity as opposed to heartbeat perception and proprioceptive accuracy moderated the association between interoceptive sensibility and well-being.

5.4. Discussion

Thus, subjective well-being is associated only with the self-reported (perceived) aspect of interoception but not related to the sensory measures of interoceptive accuracy.

6. General discussion

According to the findings of the recent thesis, interoception is a relatively stable multidimensional and multimodal construct. Therefore, whenever interoception is studied, it is highly advisable to emphasize what was the applied method and the investigated channel. My recommendation would be not to use the term 'interoception' without further description to specify the exact dimension or modality that has been assessed (e.g. interoceptive accuracy, interoceptive sensibility, cardiac interoception or cardioception, gastric interoception).

Additionally, it is recommended to examine more than one single dimension and modality in the empirical studies of interoception. This would also prevent the misinterpretation of the results, and would be more informative regarding the phenomena under study. Even if only a certain sensory modality is seemingly relevant in the particular study, the usage of an extra, (presumably) less relevant interoceptive modality is advisable.

The perception of the internal bodily information is considered to be relevant in various significant psychological phenomena. To understand their dynamics better, the empirical investigations have to take into account the multimodal and multidimensional nature of interoception.

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