

The potential role of atypical interoception in prevalent mental health disorders, interoception-based-treatment approaches and their effects:

A literature review

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I. Interoception

1. Definition

Interoception describes the ability to perceive and process the internal state of the body (2). The scientific discussion about a more precise definition has been an ongoing process for many years, as there are various lenses through which interoception can be defined and understood, e.g., endogenous/exogenous sources of stimulus or visceral/somatic receptors (3). While in the past, interoception was defined as linked to visceral information only, there has been a tendency to broaden the concept over the last decades. Contemporary definitions that are based on neural interoceptive pathways include signals relating to hunger, satiety, itch, thirst, muscular effort, bladder, gastrointestinal and respiratory, and cardiac systems, temperature, blood (pH, glucose level), headache, and more (2). These pieces of information arising from and sensed by the body add to the phenomenological experience of the body state, be it conscious or unconscious. Ultimately, the totality of these bits of information forms a representation of our physical self, created by the central nervous system (CNS) that serves to maintain bodily homeostasis. Broader definitions also include how we relate to, process, integrate, and regulate these experiences (13), acknowledging the efferent aspect of interoceptive signaling that enables the body to maintain homeostasis (12).

2. Sub-functions in interoceptive processing

Within the umbrella term of "interoception," different domains can be distinguished. These include objectively measurable parameters as well as attention and appraisal processes that can be surveyed with the help of self-report measures. Interoceptive sensitivity refers to one's objective accuracy in detecting internal bodily sensations. Interoceptive sensibility describes one's subjective belief about one's interoceptive accuracy. Interoceptive awareness refers to the metacognitive awareness of one's interoceptive abilities (11). The interoceptive attention quality can be described by the mode of attention which differentiates between a direct, experiential vs. a reflective, labeling experience of body sensations. The interoceptive attitude can be labeled as trusting or catastrophizing (13).

3. Measurement

For different reasons, the comparability and objectification of interoceptive abilities represent a challenge in the scientific field. For instance, many interoceptive processes happen unconsciously. There is a big variety in signal intensity in and between individuals, and the intensity of interoceptive experience is not inevitably related to the intensity of an external stimulus. Furthermore, the validity of non-invasive measurement/stimulation techniques for processes inside the body is limited. Currently, the majority of the studies rely on measurement of interoceptive sensitivity by heartbeat counting (HCT) or heartbeat discrimination (HDT) due to its accessibility. However, the reliability and validity of this method are disputed. Beyond that, the detection and control of gastric movements or the ability to detect breathing resistance, as a measure of respiratory interoceptive accuracy, have been used in smaller studies. An approach to identify interoceptive impairment in the emotional domain might be to investigate the presence of alexithymia. This subclinical condition is characterized by difficulties identifying and describing feelings, difficulties distinguishing emotional states from other bodily states, and a tendency to allocate attention to external rather than internal stimuli. While there is evidence that alexithymia is associated with reduced interoceptive accuracy, not all studies are consistent in these findings (2). As another option, numerous self-report measures have been developed to assess self-reported interoception, e.g., the Body Perception Questionnaire (BPQ), Multidimensional Assessment of Interoceptive Awareness (MAIA), and others. These point towards self-reported interoceptive attention and appraisal processes. At present, it remains unclear if there is a correlation between the interoceptive abilities in different sub-functions (e.g., sensitivity, sensibility, awareness) and different interoceptive modalities (e.g., gastric, cardiac, emotional). This means that the measurement of one sub-function or modality does not allow for inferences about an organism's overall interoceptive ability (2).

4. Interoceptive pathways

The understanding of anatomical structures involved in typical interoceptive processing is subject to scientific research and forms the basis for the investigation of atypical interoception as observed in certain psychiatric and somatic conditions. Current definitions of interoception are mainly based on the following neural pathways: Small afferent sympathetic nerve fibers send sensory information from the periphery of the body to the spinal cord and from here to the parabrachial nucleus, a main hub for the collection of visceral afferent information in the brainstem. Parasympathetic afferents of

the vagus and glossopharyngeal nerve (heart and digestive tract, taste, cardiac, and general visceral sensory information) project via the nucleus of the solitary tract to the parabrachial nucleus as well (2). From the brainstem, the information reaches higher cerebral cortical areas: the dorsal section of the insular cortex collects primary interoceptive information from the brainstem, hypothalamus (holds information about the current state of the autonomic nervous system and the metabolic state of the body), and amygdala (performs analysis regarding stimulus salience and emotional memories) which is then rostrally passed to the anterior section of the insula (anterior insula, AI) for further integration. From this point onwards, conscious perception of interoceptive signals is possible (11). Finally, the insula is bidirectionally connected to structures of subcortical, limbic, and executive control brain systems that serve in the contextualization of bodily information. These include, among others, the anterior cingulate cortex (ACC), which contributes to the appraisal and regulation of interoceptive signals and is part of the reward system, and the orbitofrontal cortex, which is involved in processing emotions and reward to hedonic experience (14). This linking between interoceptive and emotional or cognitive brain systems possibly leads to the generation of regulatory signals sent back to lower brain regions involved in interoceptive descending efferent systems. These descending pathways have not been incorporated into most definitions of interoception yet (4). In summary, a multitude of subcortical and cortical structures seem to be involved in interoceptive processing, with the anterior insula and anterior cingulate cortex playing a crucial role in the perception and conscious awareness of these signals (2).

5. Neurotypical interoception

In order to examine the possible relation between atypical interoception and impairments associated with a range of psychiatric and neurological conditions, it is helpful to look at the role of typical interoception in regard to two functional domains that are crucial to mental health, namely emotional processing and learning/decision-making.

Emotional processing: According to the Schachter-Singer model of emotional processing, emotions are the result of awareness of physiological arousal and cognitive appraisal of contextual cues. Therefore, the interoceptive perception of physiological arousal is likely to play a major role in the detection of quality and intensity of emotions. Evidence suggests that in typical interoception, better perception of internal signals leads to more intense experience of emotions. The identification of emotional states may facilitate targeted emotional regulation responses that are superior to nonspecific suppression strategies in regard to mental health. According to empirical evidence, interoceptive accuracy is correlated with emotional lability, emotion regulation, arousal focus, emotional intensity, and responsiveness to the emotional states of others. Neuroimaging studies consistently show activation of the anterior insula (AI) and the anterior cingulate cortex (ACC) both in the processing of one's own as well as others' emotions, while interoceptive cortex lesions have been shown to possibly impair processing of emotional, as well as non-emotional, internal states (2).

Learning and decision making: In the process of conditioning or learning, both reward and punishment (meaning positive or negative consequences following a specific behavior) evoke interoceptive signals that the individual needs to evaluate in order to adapt (e.g., subjective experience of pleasure). Pleasure, one of the main motivators for learning and decision making in favor of something, is an experiential state, which combines an interoceptive signal/sensation as well as an emotion, based on cognitive appraisal, associated with it (2).

The ability to accurately perceive interoceptive signals also forms the basis for the process of decision making as most physiologically relevant choices are aimed towards homeostasis and are linked to the present interoceptive state (2). The hedonic aspect of a stimulus, either experienced or anticipated, therefore depends both on the stimulus characteristics and the individual's state, forming the motivational basis for decision making and is perceived due to the interoceptive network. Craving and urges are important drivers of decision-making in case of ambivalence or conflict and can easily be evoked in scientific studies. Thus, neuroimaging studies have consistently produced evidence for the involvement of the interoceptive system in various urge-related behaviors (14).

II. Role of atypical interoception in prevalent psychiatric disorders

Overall, the scientific evidence suggests a fundamental role for interoception in conscious and subconscious self-perception and regulation. Interoception allows for the conclusion if the body is in/close to/far away from a state of homeostasis. The CNS's ability to secure survival by initiating a targeted and effective intervention towards homeostasis is dependent on the information about the bodily and psychic state. Both over- and under-regulated interoceptive processing may therefore lead to an inability to react to changes of the state of the body and/or environment appropriately. This ultimately increases the risk for both physical and mental dysregulation.

Even though the role of atypical interoception in pathogenesis has not been fully clarified yet, evidence suggests increased prevalence of atypical interoception across a variety of psychiatric and neurological conditions such as: Feeding and Eating Disorders (including Anorexia Nervosa, Bulimia Nervosa, Obesity), Anxiety and Panic Disorders, Alcohol and Substance Abuse, Depression, Somatoform Disorder, Autism Spectrum Disorder, Attention-Deficit/Hyperactivity Disorder (ADHD), Obsessive Compulsive Disorder (OCD), Schizophrenia, Depersonalization/Derealization Disorder, forms of Dementia (2).

As mentioned, interoception is likely to play a major role in emotional processing and learning/decision-making, two functional domains that are impaired in various of the above-mentioned conditions. The link between interoceptive impairment and clinical symptoms will be examined in three of the most prevalent psychiatric disorders, namely Depression, Anxiety Disorders, and Substance Abuse Disorders.

1. Depression

Depression is a common mental disorder with an estimated lifetime prevalence of Major Depression of 16%. Manifestation can be episodic, recurrent, or chronic and has a high rate of comorbidities such as anxiety and alcohol use disorders (15). The symptomatology is characterized by affective disorders (low mood, decreased interest and motivation, anhedonia), decreased concentration/indecisiveness, and a multitude of somatic symptoms such as altered appetite, sleeping disorders, chronic pain, fatigue, and others (18). Common risk factors include genetic predisposition, biological aspects such as temperament, and influence of learning and experience, e.g., dysfunctional cognitions leading to cognitive bias. Cognitive bias is often expressed by altered experience of the individual with respect to self, others, and the future, altered self-related processing, e.g., reduced tendency to self-favoring and/or exaggerated negative self-image (15).

As mentioned above, the insula is one of the main structures of the interoceptive network and plays an important part in the capacity to be aware of oneself (including the subjective feeling state), others, and the environment. Furthermore, it takes part in modulatory control of decision-making by interacting with other limbic and cortical areas. It is part of the neural network for self-relevant processing together with the anterior cingulate cortex and surrounding midline cortical structures as well as the medial prefrontal cortex (15). Consistent with these findings, altered structure and function of the insula have been shown in several neuroimaging studies focusing on depression. The findings include reduction of volume and thickness of the insula, reduced brain connectivity between the insula and limbic systems (involved in emotional processes), as well as altered baseline activity in the insula and hypoactivation in tasks requiring visceral interoceptive attention compared to healthy individuals. Additionally, several neuroimaging studies have shown a correlation between insular changes and severity of somatic symptoms in connection with depression (8).

In a systematic review focusing on impaired interoception in individuals with Major Depression, it was suggested that the severity of depression shows a non-linear correlation with interoceptive deficits as compared with healthy adults. Furthermore, difficulties in decision-making and low affect intensity were correlated with low interoceptive accuracy (8). This may be related to the attempt to reduce negative affect by suppressing internal signals associated with aversive emotions which may contribute to flattened affect and indecisiveness in depression (2).

Symptoms that might be related to an altered interoceptive processing include fatigue, higher sensitivity to pain, sleeping disorders, and altered appetite (12). Further research is needed to clarify the role of the interoceptive network in these symptoms.

2. Anxiety Disorders

Anxiety disorders are the most common mental health problem with a lifetime prevalence of approximately 30%. The umbrella term includes a heterogeneous group of conditions, e.g., Generalized Anxiety Disorder, Panic Disorder, Post-Traumatic Stress Disorder, Obsessive-Compulsive Disorder, Social Phobia, and (object-related) specific phobias. They all have in common intense feelings of fear/panic which result in avoidance of certain triggers (event, object, or context, which has become associated with the experience of the anxiety symptoms). Common risk factors are genetic disposition and environmental factors like stress or trauma. Certain cognitive predispositions such as increased emotional awareness or intolerance of uncertainty may contribute to the development of some forms of anxiety disorders (15).

One main role of the interoceptive network (mainly insula and anterior cingulate cortex) is the detection of salient stimuli and the anticipation of their potential impact on the organism. Neuroimaging could show an increased activation of the insular cortex while symptom provocation in anxiety patients. Also, increased anterior cingulate activity has been reported in various studies with anxiety disorder individuals. Finally, several studies found that even just the anticipation of aversive stimuli led to an activation of areas such as the amygdala, anterior insula, anterior cingulate cortex, prefrontal cortex, and orbitofrontal cortex, which are all part of the interoceptive network (15).

Generally, interoceptive accuracy has been found to be increased in anxiety/panic disorders (7), as well as levels of attention to internal signals (interoceptive sensibility as measured by the BPQ). In an interoceptive model of anxiety disorders, increased attentional biases toward threat may lead to impaired processing of afferent internal body signals (increased interoceptive sensitivity and sensibility). External cues or internal processes may generate an anticipation of aversive body states (catastrophizing interoceptive attitude) that act as a motivating signal for individuals to avoid these triggers (15). Therefore, the impairment in evaluating the potential impact of a stimulus and anticipation of harm, together with avoidance acting as a sustaining factor, are core aspects of anxiety disorders.

Possible symptoms related to impaired interoception may be palpitations, chest pain, dyspnea, choking, nausea, dizziness, flushing, depersonalization/derealization, autonomic hyper vigilance, muscle tension, headaches, fatigue, gastrointestinal complaints, and pain (12).

3. Substance Abuse Disorders

Substance Abuse Disorders (SUD) are among the most prevalent psychiatric disorders with a lifetime prevalence of 6.5% for alcohol and 8.9% for illicit drugs. SUD are defined as chronically relapsing disorders, characterized by compulsive drug-seeking behavior, loss of control in restricting intake, and emergence of a negative emotional state (e.g., dysphoria, anxiety, irritability) during withdrawal (16). Risk factors are, among others, genetic variables, and environmental factors such as family history of substance abuses, interpersonal trauma, and stress (1).

Main drivers of addictive behavior include the interoceptive experiences of arousal, attention, stress, reward, and craving (17). From the perspective of conditioning, these interoceptive states work as positive or negative reinforcers, created by drugs and related stimuli, that can be integrated into a model of atypical learning and decision-making. This is modulated by the extent to which withdrawal-related states or pleasure as an effect of certain drugs are perceived, i.e., the interoceptive processing (2).

Neuroimaging studies have repeatedly shown alterations both in the function of the insula and its connectivity to large-scale networks (e.g., salience and frontal control network) in individuals suffering from SUD compared to healthy controls. There is evidence for effects on bottom-up (e.g., abstinence state leads to activation of the insula and related networks) as well as on top-down regulation processes (e.g., imagery-induced cravings are associated with insula activation). Interestingly, and in line with these findings, lesion studies showed that the urge to smoke got lost after insular deactivation which supports the assumption that the insula plays a central role in the experience of urge/craving. Depending on substance and state (resting state vs. withdrawal), diverse studies have shown differently altered insula connectivity to the frontal control and the salience network which are involved in goal-directed behavior and detection of emotionally salient bodily signals (17).

At this time, only few studies have investigated interoceptive sensitivity or accuracy in substance using individuals. Yet, there is evidence suggesting that interoceptive accuracy

is lower in individuals addicted to alcohol, while the interoceptive sensibility is higher compared to healthy controls (19).

III. Interoception-based interventions

It should be emphasized that the role of atypical interoception in prevalent psychiatric conditions (e.g., as possible symptom, cause, and/or maintaining factor) has not been finally clarified yet. This is partly due to the novelty of this branch of research and the difficulties in objectifying and measuring interception, as mentioned above. Still, the previous sections encourage the assumption that alterations in the interoceptive network (as shown in neuroimaging studies) and interoceptive capacities (as objectively measured by interoceptive sensitivity or subjectively measured by self-report measures) are frequently associated with clinical conditions such as depression, anxiety disorders, substance abuse disorders, and more.

Not surprisingly, attempts have been made to develop Interoception-Based Interventions to target symptoms that might be caused by interoceptive impairment. Interoception-Based Interventions (IBIs) are defined as interventions that include “first-person reflection upon or cultivation of specific modes of experience, and practices that explicitly involve interoceptive awareness” (10). The following sections aim to give an overview of different treatment approaches targeting interception, their objectives, and the state of research on their effectiveness.

1. Treatment approaches relevant to interoception in mental health disorders

Among the currently available IBIs, the most common ones include medication, psychotherapy, mindfulness, and movement. Medication-based approaches are targeted at the modulation of the interoceptive experience itself, e.g., with the help of adrenergic blockage, muscle relaxation, or CNS depression/stimulation. Some psychotherapy and mindfulness-based interventions focus exclusively on increasing interoceptive sensitivity and sensibility (e.g., breathing exercises), while others focus on the metacognitive appraisal of or reflection on interoceptive signals. Some interventions combine both: attention to bodily signals and reflection upon them (10). One example of the latter is cognitive-behavioral therapy (CBT) with interoceptive exposure and cognitive reappraisal of interoceptive experiences. Interoceptive exposure has been proven effective in panic disorders and irritable bowel syndrome. Bringing awareness towards positive interoceptive states is used in therapeutic concepts for depression and binge eating disorders. Mindfulness-based treatments such as MBSR and contemplative techniques include increasing metacognitive awareness and find use in the treatment of chronic pain, substance abuse disorders, and others (12). Trauma Center Trauma-sensitive Yoga (TCTSY) is a body-based intervention used in the treatment of PTSD and cPTSD, which focuses on reducing stress reactions of the body by cultivating interoception (5).

2. Therapeutic objectives in relation to interoceptive regulation

Except for medication-based interventions, which aim to modify the interoceptive experience or even physiological reaction itself, the other interventions are targeted at modifying interoceptive capacities or handling of interoceptive experiences, summarized

as interoceptive regulation. Interoceptive regulation is defined as “how well a person can match an interoceptive signal to his or her desired state.” This definition is in line with a prediction error model of interoceptive inference, called the simulation map. The simulation map is an integrated, abstracted, and interpreted representation of the current body state that is constantly being checked against ‘raw’ ascending interoceptive signals. In case of unexpected interoceptive events, an inference response is being triggered (9).

Here, active inference techniques can be differentiated from perceptual inference techniques. Active inference includes psychological/behavioral responses that are intended to change the interoceptive milieu to match expected states, e.g., by reappraisal, suppression, or distraction. For instance, cognitive-behavioral therapy aims at shifting the interoceptive attitude (trusting vs. catastrophizing) by modifying dysfunctional appraisals, such as interpretation of interoceptive signals as threatening in panic disorders (13). In contrast, the process of updating the expected simulation map to more accurately reflect immediate sensation is known as perceptual inference. This is in line with contemplative traditions using continuous non-interfering observation, as ways of changing one's attitude toward a sensation (i.e., interoceptive mode of attention) rather than attempting to change the sensation itself (8). One example of an adaptation of the latter in the context of psychotherapy is the concept of “observe and describe” used in Dialectical Behavior Therapy, which aims at facilitating an experiential, immediate, and non-judgmental (interoceptive) experience (13).

3. State of research on the effectiveness of IBIs

Generally, there is evidence that IBIs might help improve interoception in certain mental health disorders and reduce mental health symptoms. In a systematic review of randomized-controlled trials on psychological interventions for interoception in disorders associated with mental health symptoms, 64.5% of the studies concluded that IBIs were more effective at improving interoception compared to control conditions, especially in Post-Traumatic Stress Disorder, Irritable Bowel Syndrome, Fibromyalgia, and Substance Abuse Disorders. Concerning symptom improvement associated with IBIs, indicative evidence of efficacy was observed in Eating Disorders, Irritable Bowel Syndrome, and Substance Abuse Disorders. The most effective treatment approach was shown to be a combination of reinforcing the experience of interoceptive signals (interoceptive sensitivity and sensibility) and their metacognitive appraisal (interoceptive awareness, attitude, and mode of attention). In this review, no evidence for improvement of mental health symptoms could be found for Chronic Pain, Depression, Anxiety and Depression, Autism Spectrum Disorder, and sleep disturbances (10).

A recent randomized clinical trial on trauma-sensitive Yoga (TCTSY) for Post-traumatic Stress Disorder in women veterans showed equivalent effectiveness in the reduction of PTSD symptoms compared to the gold standard treatment (cognitive-behavioral therapy). Even though interoceptive regulation was not explicitly measured or inquired, interception was highlighted as a core component of TCTSY (5).

In another review of randomized controlled trials with IBIs in psychiatric disorders, seven out of fourteen studies revealed statistically significant positive results with respect to primary outcomes and interoceptive measurements. Those included interoceptive exposure and aspects of interoceptive regulation as part of the treatment of Panic

Disorders and Irritable Bowel Syndrome, self-monitoring based on interoceptive experiences in Binge Eating Disorders, and other interventions using mindfulness-based approaches in the treatment of Substance Abuse Disorders and Chronic Pain (13).

In this context, it should be pointed out that the differentiation between solely interception-based interventions and mindfulness-based interventions is not always clear. Mindfulness is defined as „an open, engaged, and non-judgmental awareness of the ongoing flux of present moment experience, including internal experiences of sensations, thoughts, and feelings, as well as exteroceptive sensations“ (9). Even though many contemplative practices explicitly involve direction of attention to interoceptive experiences, the use of diagnosis-independent, interoceptive questionnaires such as MAIA (Multidimensional Assessment of Interoceptive Awareness), is still rare in clinical intervention studies. This makes it hard to draw conclusions about the role of interoceptive aspects included in the majority of mindfulness-based interventions. However, there seems to be a big intersection in the effects of interoception- and mindfulness-based trainings. Various studies have shown not only increased heart beat accuracy after mindfulness-based contemplative interventions, but also alterations in brain function and structure in regions that are thought to be involved in body awareness, such as the insula. Different studies on mindfulness-based treatment of chronic pain (1) and depression (6) gave evidence for increased quality of interoceptive processing, e.g., enhanced attention towards body sensations or body trusting as measured by MAIA.

At this point, it can only be referred to the extensive literature on the health benefits of mindfulness approaches, of which the discussion would go beyond the scope of this research.

IV. Conclusion

In summary, interoception encompasses the ability to perceive and process the internal state of the body, including regulatory responses to various bodily signals. It involves a network of subcortical and cortical structures, with the anterior insula and anterior cingulate cortex playing pivotal roles. Interoception is crucial for emotional processing and learning/decision-making in healthy individuals. Evidence suggests increased prevalence of atypical interoception across various psychiatric and neurological conditions such as depression, anxiety disorders, and substance abuse disorders. Interoception-Based Interventions (IBIs) include medication, psychotherapy, mindfulness, and movement, with most interventions aimed at modifying interoceptive regulation rather than the interoceptive experience itself. There is evidence indicating that IBIs can improve interoception in certain mental health disorders and reduce associated symptoms, particularly when combining attention to bodily signals with reflection upon them. Effective IBIs have been observed in panic disorders, irritable bowel syndrome, binge eating disorders, and PTSD. There is also a significant overlap between the effects of interoception- and mindfulness-based trainings. However, further research is needed to deepen our understanding of the role of atypical interoception in psychiatric disorders and to advance the development of IBIs.

V. Literature

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