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The Re-Embodiment Project: Exploring the Role of Interoception and Embodiment in Anorexia Nervosa

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IN THIS FEATURE, we will try to describe the characteristics of current cyberpsychology research in Europe. In particular, CyberEurope aims at describing the leading research groups and projects running on the other side of the Ocean.

Introduction

Anorexia nervosa (AN), a distressing mental health condition characterized by a restriction in caloric intake significantly below one's nutritional requirements, has the second highest mortality rate of all psychiatric conditions.[1] Body distortions, namely an overestimation of one's shape or weight, are frequently observed in AN and are thought to be implicated in the cause and maintenance of this condition. These body distortions are typically regarded as emerging from a cognitive bias, or thinking style, meaning that treatment approaches for AN are primarily based upon cognitive-behavioral approaches which seek to challenge distorted beliefs about the body. However, current therapeutic interventions for AN fail to show significant improvements in clinical symptoms and weight gain, relative to control groups.[2] Therefore, there is a fundamental need for a paradigm shift in how AN is conceptualized and subsequently treated.

Interoception and the Self

Our sense of self can be defined as the sense of belonging within a body, within our environment.[3] Accordingly, this definition considers selfhood as comprising two components: (1) our sense of existing within our environment, which we gain from integrating external sensations such as vision and hearing and (2) our sense of existing within our bodies, which emerges from the integration of internal sensations arising from the body's viscera, such as the heartrate, or hunger levels. This latter component is thus contingent upon a person's interoceptive abilities, their ability to accurately perceive and integrate the internal sensations arising from their body (e.g., the heartbeat).

Interoception is a vital sense. Besides its critical role in developing a sense of self, interoception is also implicated in other key psychological and physiological processes including emotional regulation, homeostasis, and social cognition.[4] Yet, interoception is not a passive process. Rather, models of interoceptive inference consider interoception as arising from the multisensory integration of incoming internal sensations (afferent signals) with top-down predictions about the nature of the signals received.[5] The ability to accurately predict one's internal state is fundamental to the maintenance of optimal physiological and psychological states—through building accurate models, we are able to pre-empt and respond optimally to changes in the external environment which may disrupt the internal milieu. Consequently, in situations where predictions do not align with incoming sensory information, provided the incoming sensory signal is both reliable and salient, predictions will be updated. In turn, this updating process ensures that accurate models will be generated in future encounters with the same context.

(Dis)Embodiment in AN

Several lines of evidence suggest that this process of interoceptive inference is disrupted in AN. Specifically, it is thought that afferent interoceptive signals become "noisy" or

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unpredictable, which renders these streams unreliable. As a result, incoming interoceptive information is thought to become attenuated in AN leading to an overreliance upon external signals and predictions to form a sense of self. Moreover, as interoceptive streams are attenuated, conflicting sensory information encoded within these streams is not used to update predictions, resulting in the development of increasingly rigid models of the body's internal state which ultimately may lead to a detachment of the sense of self from the inner body. In essence, individuals with AN become "disembodied."

Developing this concept further, the allocentric lock hypothesis (ALH[6]) proposes that AN primarily arises from a deficit in multisensory integration of the self. Specifically, two core multisensory integration deficits are proposed. First, there is thought to be a deficit in the integration of incoming sensory information about the body encoded within the egocentric self-reference frame with stored, third-person representations of the body's metric properties encoded within the allocentric self-reference frame. As a consequence, individuals become reliant upon the allocentric reference frame, viewing themselves from a disembodied, third-person, objectified perspective through the lens of negative self-schemas encoded within this frame. Moreover, a failure to integrate new sensory information encoded within the egocentric reference frame into the allocentric reference frame results in the stored body representation failing to update with changes to the body's size. Hence, individuals with AN become trapped to an outdated body representation that fails to update with weight loss, resulting in distress and increasingly extreme attempts to lose weight.

Second, the ALH proposes that deficits in the multisensory integration of interoceptive signals into the sense of self further exacerbates these effects by increasing detachment from the self and leaving individuals unable to link internal signals to their pleasant, or aversive emotional consequences. The net result of these multisensory integration deficits is therefore a state of disembodiment, which leads to increased self-objectification, emotional dysregulation, and the development of distorted body representations which ultimately both cause and reinforce AN behaviors.

The Re-Embodiment Project

If evidence is found to support the core tenets of the ALH, then this would suggest interventions aiming to restore the integration of interoceptive signals may be effective for the treatment of AN. Therefore, the goal of the Re-Embodiment Project is to both investigate key questions arising from the ALH and to develop new interventions for the treatment of AN across two phases. This research has received funding from the Economic and Social Research Council [Grant No. ES/P000665/1] and will be conducted by researchers from Lancaster University; Birkbeck, University of London; and the Greater Manchester Mental Health NHS Foundation Trust; in collaboration with the Catholic University of the Sacred Heart of Milan, Italy.

Phase 1: Evaluating the ALH

In Phase 1, two core studies will be conducted to address key questions arising from the ALH. Specifically, Study 1 will aim to answer the questions: (1) Can people with AN update their stored body representations with changes to their body's size? and (2) How does the ability to update stored body representations relate to a person's interoceptive abilities? Study 2 will consider the questions: (1) Do people with AN integrate interoceptive signals into their sense of self? and 2) How does the integration of interoceptive signals relate to a person's emotion regulatory abilities?

Study 1. Study 1 will consist of three experiments. In the first experiment, participants will make estimates of their maximum grasping capability (estimating the largest block they think they can grasp); in the second, participants' maximum perceived reaching ability (the furthest point they think they can reach without leaning forward) will be measured; and, in the third experiment, participants will estimate their aperture passing capability (the minimum opening through which they think they can walk through without rotating their shoulders). In each experiment, the size of the body part performing the action (i.e., the hand, arm, or shoulders for grasping, reaching, and aperture passing, respectively) will be manipulated to be small, medium, or large in size, with each size forming a separate condition.

In the physical environment, inducing alterations to a person's body morphology would be a largely impossible task. However, through using virtual reality technology, we are able to alter a person's perceived body part size through having them embody realistic humanoid avatars whose body parts have been distorted. After a series of calibration trials, findings from previous research would lead us to expect nonclinical controls to incorporate the morphological size change into their body representation, resulting in an adjustment in participants' perceived action capability (the maximum extent to which they can perform a given action in a specific context, e.g., the farthest distance they can reach) in the direction of the morphological distortion (e.g., greater maximum perceived reach in the large arms condition, relative to the medium arms condition). However, based upon the predictions of the ALH, we would expect that people with AN will not be able to update their stored body representations to accommodate the morphological change. Hence, in this group, we would not expect to see an adjustment of maximum perceived action capability across conditions. Nevertheless, it is possible that people with AN will perceive a visual change in the size of the body parts, which may result in an adjustment of their estimates, even if the morphological change does not elicit an updating of the body representation. To account for this, we will also consider participants' *accuracy* across conditions, which is calculated by dividing participants' estimated action capability by their actual capability in each condition. Thus, it is in this latter dependent variable we would expect to observe the greatest differences between AN and controls. Specifically, we expect to observe lower accuracy in the AN group across conditions and experiments, compared with that of controls.

To understand how interoception relates to individuals' ability to update their body representations, Study 1 will also take a measure of participants' interoceptive abilities. To do this, participants will be asked to count how many heartbeats they can feel over different time periods. This will be compared with the actual number of heartbeats that occurred to

provide a measure of how accurately the participant perceives their internal sensations. In addition, we will measure participants' confidence in their ability to sense their internal sensations and how this relates to their accuracy on the task. We will then determine which factors predict task performance in each group (AN and controls) for each of the experiments by modeling the extent to which interoceptive measures, as well as clinical variables including eating disorder symptomology, body dissatisfaction, self-esteem, and body mass index (BMI) predict the outcome. If interoception is related to a person's updating ability, then we would expect that greater interoceptive accuracy would be related to greater accuracy across experiments. By modeling the factors which predict task performance in each of the groups, we are therefore able to understand not only whether body representations are updated in AN, but also whether the factors that predict an individual's performance on this task differ between AN and nonclinical controls. In turn, this can provide insight into whether there are specific predictive factors, such as interoceptive abilities, which may be a useful target for future therapeutic interventions.

Study 2. In Study 2 of Phase 1, we intend to use virtual reality technologies to investigate how interoceptive signals are used to form a sense of self in AN. To do this, we will employ the virtual full body illusion paradigm, which involves manipulating the congruency between a virtual avatar and the participant and measuring how this affects embodiment of the virtual body. If greater congruency between the person and the avatar results in enhanced feelings of embodiment, then it is likely that the feature being manipulated is being utilized to establish a sense of self or body ownership.

Interoceptive congruency can be manipulated in the virtual full body illusion through either changing the degree to which the avatar's chest movements match the respiratory rate of the participant (embreathment full body illusion), or through adjusting the rate at which the avatar's silhouette flashes such that is synchronous or asynchronous with the participant's heartbeat (heartbeat full body illusion). In healthy individuals, embodiment in both manipulations is more enhanced in conditions of synchrony versus asynchrony, which implies that interoceptive signals are used to form a sense of self (i.e., the boundaries of what is *my* body) in nonclinical individuals. Hence, the interoceptive virtual full body illusion is a powerful paradigm for investigating whether interoceptive signals are integrated into the sense of self in AN. Specifically, if interoceptive signaling is attenuated in AN, then we would expect to see no change in embodiment across conditions of synchrony or asynchrony for neither the heartbeat, nor the embreathment interoceptive illusion. Instead, if the sense of self is primarily derived from exteroceptive stimulation in AN, then we would expect to see high levels of embodiment in both conditions. This is because the congruency between the avatar and the participant in terms of body positioning and visual perspective may foster stronger experiences of embodiment in a group reliant upon visual information for forming a sense of self.

Therefore, in Study 2, the effects of interoceptive synchrony on embodiment will be compared between AN and nonclinical controls for both the heartbeat and the embreathment virtual full body illusions. Each illusion will form a separate experiment and different components of embodiment will be assessed using questionnaire measures. Both the heartbeat and the embreathment illusion will be used to determine whether the effects of congruency on embodiment are also contingent on the type of interoceptive signal. Furthermore, to investigate how the integration of interoceptive signals impacts on emotional regulation, Study 2 will also incorporate measures of emotional arousal. Specifically, in each experiment and condition (synchronous and asynchronous), physiological measures of arousal will be obtained including skin conductance responses and heartrate variability. In addition, behavioral measures of arousal will also be taken through having participants rate their levels of emotional arousal using visual analogue scales, whilst situated within the virtual environment. We expect to observe lower levels of emotional arousal in controls in the synchronous condition relative to the asynchronous condition. This is because, in the synchronous condition, there is congruency between the participants' perceived internal signals and the avatar and therefore a prediction error is not triggered. Whereas, in the asynchronous condition, the incongruency between the avatar and the person's internal sensations may elicit a higher state of arousal through the triggering of a prediction error. In contrast, in AN, we would not expect a difference in emotional arousal to be observed across conditions. This is because, if interoceptive prediction errors are attenuated in AN, then any prediction error triggered by the asynchronous condition should not elicit a hyperaroused state. Instead, we would expect to observe a state of low emotional arousal across conditions.

Phase 2: Developing interventions for the treatment of disembodiment in AN

Phase 2 aims to test the efficacy of new, noninvasive interventions for AN which seek to restore multisensory integration of interoceptive signals into the self. To this end, two possible interventions may be evaluated. The first intervention that may be assessed is heartrate variability biofeedback therapy. In heartrate variability biofeedback therapy, individuals are trained to constrain their heartrate variability (the variation in time between heartbeats) within optimal parameters through the use of a breathing technique known as "resonance frequency breathing." Resonance frequency breathing involves inhaling and exhaling at a rate (typically ~ 6 breaths per minute), which maximizes a person's heartrate variability. Individuals are provided with an online visual display of their heartrate signal to aid them in optimizing their breathing. Breathing at one's resonance frequency is thought to stimulate the vagus nerve, which in turn connects to brain regions implicated in the integration of interoceptive signals, namely the insula and anterior cingulate cortices. Thus, through enhancing the stimulation of interoceptive brain regions, it is thought that heartrate variability biofeedback may have potential as an intervention for improving the integration of afferent interoceptive signals.[7]

The second intervention that may be employed is that of sonoception. In this intervention, individuals are exposed to auditory stimulation at a frequency of 6 Hz. It has been shown that stimulation at this frequency elicits increased neural signatures of heartbeat detection, as well as enhanced activation of the left insula, relative to a stimulation of 2 Hz.[8] Therefore, there is evidence to suggest that sonoception

enhances the cortical processing of interoceptive signals and, hence, may be a useful intervention for the restoration of optimal interoception over a series of treatment sessions.

For either intervention being assessed, both nonclinical controls and individuals with AN will be included. Participants from each group will be allocated to a treatment group or a sham-treatment group. Participants will receive eight weekly sessions of their allocated intervention. To evaluate the effectiveness of the treatment, several physiological and psychological measures will be obtained before and after the intervention. First, both before and after the intervention, participants will complete the same virtual full body illusions and procedure as used in Study 2 of Phase 1. In doing so, we will be able to map whether changes in the integration of interoceptive signals and emotional regulation occur as a result of the intervention. In addition, behavioral measures of interoception will be obtained to determine whether the accuracy and confidence with which participants perceive their internal sensations is improved after completing the intervention conditions. Furthermore, to corroborate these behavioral measures of interoceptive abilities, measures of physiological (i.e., heartrate variability) and neural activity (i.e., neural signatures of heartbeat detection), both at rest and while performing the behavioral interoceptive task, will be obtained both pre- and postintervention. Finally, changes in clinical symptomology (eating disorder symptoms), body dissatisfaction, and BMI will also be assessed to determine whether changes in interoception relate to changes in clinical outcomes. Thus, through completing this battery of different measures both pre- and postintervention, we will be able to generate a multidimensional picture of how the intervention impacts on the integration of interoceptive information across behavioral, physiological, and neural indices, as well as how clinical outcomes (eating disorder symptoms and BMI) are affected. Consequently, the findings of Phase 2 will be highly informative as to the potential of interoceptive interventions for the improvement of clinical symptoms in AN.

Conclusion

AN is a complex mental health condition with severe consequences for health and wellbeing. The limited efficacy of current interventions presents the need for a shift in the way AN is conceptualized and subsequently treated. The ALH proposes that AN is a condition of disembodiment arising from a deficit in the multisensory integration of self-reference frames and interoceptive signals. Through testing the core tenets of this hypothesis, the Re-Embodiment Project will enhance understanding of potential factors implicated in the development and maintenance of AN. Moreover, through evaluating the effects of interventions designed to restore optimal interoception on clinical outcomes in AN, this project will pave the way toward the development of more efficacious treatments. The Re-Embodiment Project has the potential to greatly enhance treatment outcomes for people with AN, helping to increase the likelihood of recovery and improve individuals' quality of life.

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