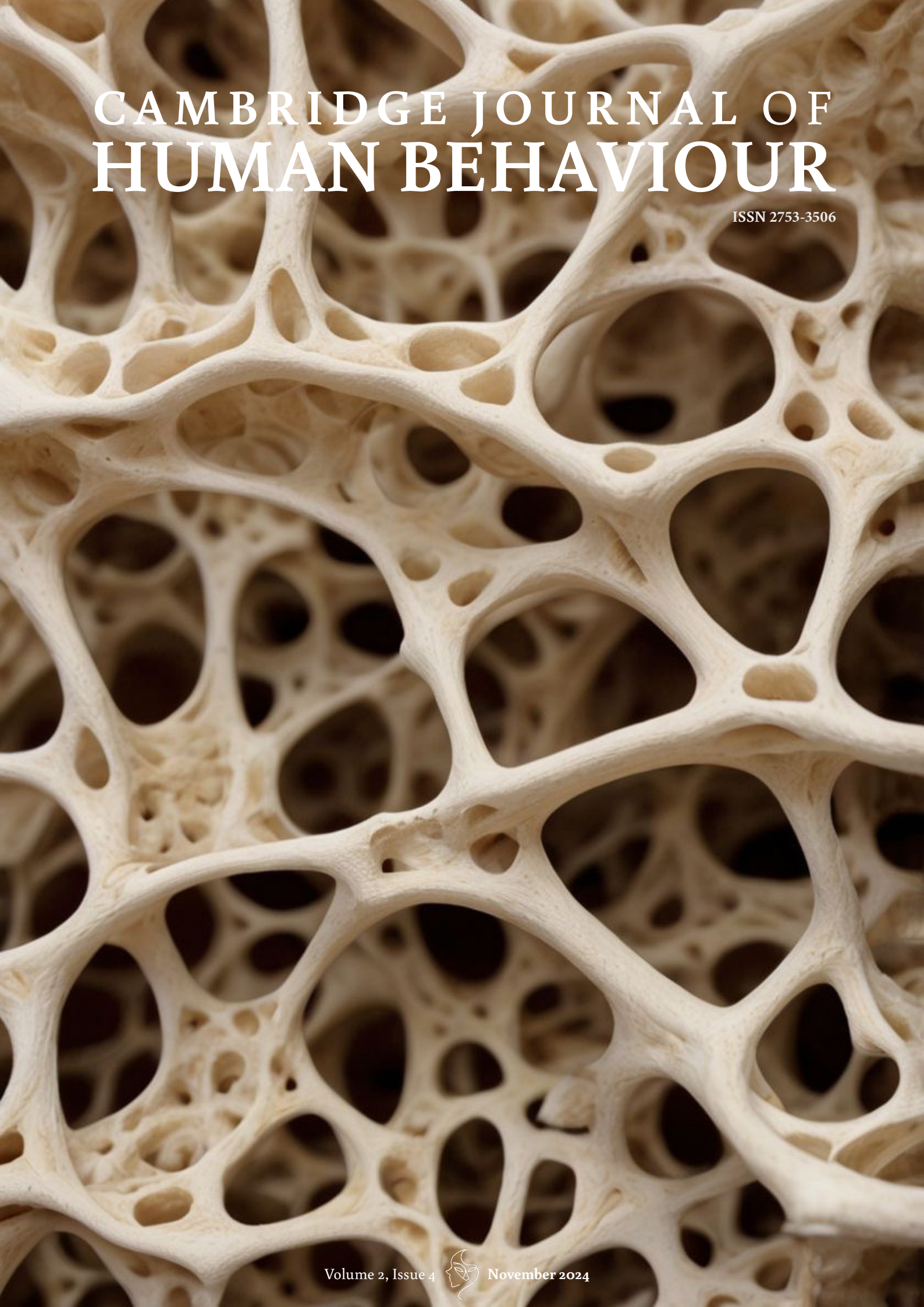

CAMBRIDGE JOURNAL OF HUMAN BEHAVIOUR

ISSN 2753-3506

Volume 2, Issue 4 November 2024

CAMBRIDGE JOURNAL OF HUMAN BEHAVIOUR

Published by *Cambridge Journal of Human Behaviour*, Cambridge, United Kingdom.

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ISSN	2753-3506
Journal Type	Diamond Open Access
Review Type	Collaborative, double-blind
Published	Quarterly
Reference Style	APA 7

CAMBRIDGE JOURNAL OF HUMAN BEHAVIOUR

Volume 2, Issue 4 | **November 2024**

CAMBRIDGE JOURNAL OF HUMAN BEHAVIOUR

Contents

Editorial

The fourth issue of volume two marks the second anniversary of the *Cambridge Journal of Human Behaviour*, which is a remarkable achievement for any new endeavour — especially one run by students. When the first issue of the journal was released, the same students who are now approaching their gruelling final year were wide-eyed freshers. Hopefully, we will soon see fantastic submissions from students who encountered the journal right at the very start of their university journey. I am very excited about this issue, as the articles demonstrate the important fields of study that undergraduate students are pursuing. It is a great pleasure to work for a journal that platforms the high-quality research of undergraduates.

Two of the articles in this issue study mental health and disability, demonstrating that young people are very keen to lead research into difficult and stigmatised fields to help marginalised people. One of the many benefits of interdisciplinary research is the ability to look broadly across fields and bring together different disciplines to propel research into these vital and relevant topics. In this issue, our psychology division presents two fascinating articles in critical fields of study.

Comber contrasts the effects of selective serotonin reuptake inhibitors (SSRIs) and deep brain stimulation (DBS) on obsessive-compulsive disorder (OCD). Selective serotonin reuptake inhibitors are a common and effective short-term treatment for OCD; however, Comber iterates some of the side effects and long-term consequences of the treatment. The article then contrasts that common treatment of OCD with a more experimental treatment, Deep brain stimulation, which may present longer-lasting beneficial effects, although further research is necessary. Comber pinpoints an important issue in mental health treatment and demonstrates the benefits of exploring alternative treatment.

The psychology division also presents an article by Nisa Binti Amat Jafri analysing facial expressions and body posture in relation to autism spectrum disorder (ASD) traits. Nisa Binti Amat Jafri concluded that those in a neurotypical population with ASD traits may face difficulty in social settings as multiple inputs contribute to emotional recognition. The article seeks to raise awareness for the ASD community to lessen their challenges in communication.

Finally, I am excited about a fascinating submission for the biological anthropology division from Schwartz and colleagues. The study utilised micro-CT scans of adult hominoid clavicles to examine forces within the bone across several genera. The article hopes to contribute to the understanding of bone mechanics that could have implications for the medical field and our understanding of evolutionary changes in the shoulder.

This is likely Liam's last issue as Editor-in-Chief and I wanted to take this opportunity to thank him for his tremendous leadership over the previous year and a half. I took over as Managing Editor of Biological Anthropology from Liam in early 2023 and have greatly appreciated his continued support. Under his leadership, the journal has grown extensively and now reaches many universities around the world. Last but never least, thank you always to the editorial board, reviewers, copyeditors, and authors that ensure the next generation of freshers see their undergraduate research in print.

Jasmine Regan Feldman

Managing Editor, Biological Anthropology

CAMBRIDGE JOURNAL OF HUMAN BEHAVIOUR

PSYCHOLOGY

The Effect of Facial Expression Recognition & Autistic Traits on the Recognition of the Emotional Content of Body Postures

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Received October 31, 2023
Revision received September 27, 2024
Accepted September 28, 2024

Keywords:
social perception,
facial expression,
body posture,
autistic traits,
emotion recognition

Autistic-related traits are often associated with a reduced ability to integrate visual stimuli with other sensory information, leading to challenges in processing and responding to the environment. Based on previous literature, it is known that during emotion recognition processes, body posture influences facial expression processing. However, there is little research on the opposite effect. Therefore, this study investigates if facial expression stimuli have an effect on body posture stimuli processing with regard to recognition of emotional expression in the neurotypical population. 70 participants took part in the study. They were required to complete a perceptual task and the Autism Spectrum Quotient (AQ-50) questionnaire. Firstly, this study hypothesised the recognition of emotion through facial expression stimuli has an effect on the body as a contextual cue. Secondly, this study also hypothesised a negative correlation between the AQ-50 scores of neurotypical university students and the influence of facial expressions on the recognition of the emotional content of body postures. The study's result suggests there is a perceptual bias of facial expression on the interpretation of the emotional states conveyed by body posture. However, no significant relationship was found between autistic traits (measured by an AQ-50 score) and the influence of facial expression on judgement of body posture (measured via point of subjective equality; PSE) shift.

INTRODUCTION

Emotion recognition

Humans often convey their emotion in a social context through language, vocal and facial expression. Emotion recognition can be defined as the attribution of emotional states obtained from visual and nonverbal cues (Bänziger, 2014). Emotion recognition serves a variety of functions including allowing mutual understanding and trust in a social setting (Elfenbein & Ambady, 2002). Nonverbal signals can be obtained from expressions on a person's face, and gestures when communicating. Suslow et al. (2020) concluded that facial expressions contain many emotional cues that can reflect mental states. According to Song (2021), language, vocal expression, and facial expression contributed 7%, 38%, and 55% respectively, of information during emotion processing. This shows that non-linguistic cues are significantly more effective than linguistic cues in conveying information. To understand how emotional cues are communicated, we must first understand how emotion is perceived.

Context-dependency of emotion recognition

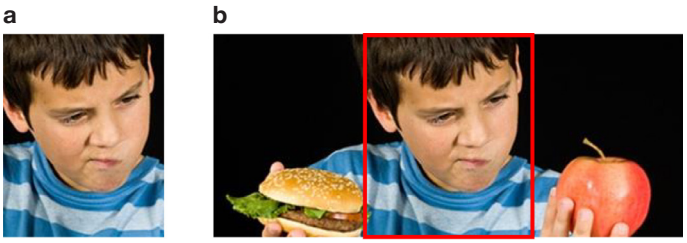
There are several processes involved in emotion recognition. Adolphs (2002) outlined different parts of the brain that were activated when emotion is perceived, and each brain part processes different functions in their role in emotion perception. For example, the fusiform face area (FFA) is activated as it recognises the face of a subject, the superior temporal sulcus (STC) is activated in response to eye gaze (Adolphs, 2002), and the amygdala plays a role as a danger detector or a socio-emotional processing submodule (Zalla & Sperduti, 2013). All of these functions have direct or indirect roles in early visual processing to perceive emotion. Early visual processing involves global and local aspects. Typically, information is processed through global processing as it is more automatic and schematic, while local processing requires more effort. In emotion recognition, it is important to understand and integrate all emotional cues such as facial expression and body posture.

Research shows it is difficult to perceive emotion solely depending on facial expression or body context in isolation. For example, in Wang et al. (2022), when participants were shown the same facial expression in different contexts, different emotions were categorised by the observer. In **Figure 1a**, the facial expression that is shown by Wang et al. (2022) can be perceived as vague, and thus categorised as either anger or confusion; however, when the stimulus is paired with a bodily context, where one hand is holding an apple and the other is holding a hamburger (**Figure 1b**), then it becomes obvious to say that the expression conveyed is one of confusion. In **Figure 1b**, the shoulder also plays a role as an environmental cue to categorise the emotion.

This argument is supported by findings in Hassin et al. (2013), where body posture has a strong influence on facial expression in recognising emotion. They argue that configurations of facial muscles are ambiguous and emphasise that context not only modifies but can lead to radical categorical changes in emotion perception. The influence of body posture is an automatic process in perceiving emotion (Brewer et al., 2017). This outlined that the global processing style is performed when emotional cues were perceived; however, this challenges the traditional idea that emotions can be directly read from facial muscle configurations (Nakamura et al., 1990). This paper also suggested that emotion categorisation is more complex and context-dependent than previously assumed.

Figure 1

The illustration of facial expression in emotion recognition



Note. This figure is obtained from Wang et al. (2022).

The discussion about the confusability effect implies that similar facial expressions may be easily influenced by contextual cues. Processing the facial features is an important aspect of emotion recognition however it is not always sufficient to generate information about what emotion is conveyed.

However, under certain circumstances, local processing will take place. Local processing is more detail-oriented, where a specific detail of a stimulus is focused on rather than the whole stimulus. People with autism spectrum disorder (ASD) demonstrate more local processing styles compared to the neurotypical population (Happé, 1999). Happé (1999) also outlines that people with ASD neurotypically show greater attention to detail compared to the neurotypical population. They tend to employ a bottom-up strategy where individual cues are perceived to create a whole perspective. The bottom-up strategy indicates that the processing starts from the basic sensory data and progresses upward through the brain's neural pathways. People with ASD may experience sensory overload, which can interfere with the ability to process and interpret emotional cues in a social context (McRae et al., 2011). Bottom-up processing involves directing attention to salient social cues in the environment. People with ASD may have a limited social attention span, focusing more on local specific details or objects rather than the global broader social context, which can affect their ability to pick up on emotional cues from others (McPartland et al., 2010). Consequently, this often causes delays in social communication.

Autistic traits in neurotypical populations

In the typical population, people with autistic-related traits are distributed on a continuum, where ASD represents the extreme end of this range (Koolschijn et al., 2015). The main autistic-related traits that have been usually observed are deficits in social behaviour and communication (McPartland et al., 2010). As long as the traits do not disrupt ordinary mental and physical function, they will be considered subclinical.

According to the latest edition of Diagnostic and Statistical Manual of Mental Disorders (DSM-5), this impairment is caused by poor integration between eye contact and body gesture resulting in a lack of awareness of facial expressions (American Psychiatric Association, 2022). Individuals with ASD were found to be less likely to look at faces in social scenes, making emotion recognition difficult (Riby & Hancock, 2008). Previous research also found that people with ASD showed a reduced preference in attending to global properties (Koldewyn et al., 2013). Global processing plays a role in social cognition, including understanding social cues and intentions. When global processing is reduced, individuals may have difficulty integrating complex social cues, such as eye contact and body gestures. Individuals may pay more attention to local details, such as specific body gestures or facial expressions, rather than integrating these cues with the broader context of eye contact.

However, McKenzie et al. (2018) replicated the study with 256 participants (75 males, 117 females, 5 bi-gender/transgender, 59 did not respond). They studied the relationship between autistic-related traits, measured using AQ–50 score (Baron-Cohen et al., 2001), and Emotion Recognition (ER) task variables. During the ER task, participants were presented with a list of emotions depicted in photographs. Participants were required to name the emotion depicted to respond to each question

Figure 2

Facial expression of one male identity presented in face-only condition

Note. (**a**) indicating 100% angry facial expression and (**b**) indicating 100% disgust facial expression from the NimStim (Tottenham et al., 2009).

as "happy", "sad", "worried", "afraid", "angry", "surprised", "disgusted", "bored", or "neutral". McKenzie et al. (2018) found that participants with higher autistic-related trait scores were associated with reduced accuracy in general ER tasks; however, while the overall AQ-50 score was associated with ER performance, the AQ-50 score was not associated with processing style, and processing style was not associated with ER performance.

This lack of association however could have resulted from the study conditions, under which there is no time limit given while performing the ER task. This could allow individuals with ASD or high autistic-related traits to switch from local to global processing. Further research has compared the nature of processing style or emotion recognition with and without time limits using both static and dynamic stimuli. Besides, more females than male participants took part in this study. In the general population, females are known to perform better in emotion recognition tasks compared to males (Kret & de Gelder, 2012). Therefore, a higher sample size of male participants in further research may have increased the power to identify if the effects are varied by sex. Specifically, the study shows people with autistic-related traits are associated with poor emotion recognition in the general population, not just in individuals who have been diagnosed with ASD.

Shortcomings in emotion recognition

Recent studies address the role of body posture as a contextual cue in emotion recognition (Brewer et al., 2017; Buisine et al., 2014). There are some studies (Adolphs, 2002; Bänziger, 2014) focused on how facial expression influences emotion recognition; however, these studies often neglect further contextual factors such as posture, movement, speech, and environment, leading to debate about their validity. Previous researchers (Teufel et al., 2019; Brewer et al., 2017) found that emotion recognition is context-dependent and often involves holistic processing, but there are not many results that directly address the role of facial expression as the contextual cue in emotion recognition. A study by de Gelder et al. (2006) showed that facial expression is a salient contextual clue and is not standalone in its importance. Facial expression usually occurs within a context of head and body orientations, body movements, posture changes, and other object-related actions with similar meanings. The author suggested that cues from the environment or context in which a facial expression occurs may directly relate to the displayed emotion. For example, a frightened face might be accompanied by corresponding withdrawal movements of the head and shoulders when confronted with external danger. Therefore, this study is particularly interested in exploring if there is a relationship between facial expression as contextual cues within the context of emotional recognition.

This study is also interested in measuring emotion recognition in people with autistic traits. Brewer et al. (2017) carried out several studies focusing on how the body as a contextual cue influences the recognition

Figure 3

Body posture of one male identity presented in body-only condition

Note. Body postures drawn from a morph continuum blending angry and disgust emotions in 10% increments using FantaMorph Pro (Version 5).

of emotions in facial stimuli among people with and without ASD. The researchers aimed to investigate whether individuals with ASD, who are thought to have difficulties integrating information from different visual regions, exhibit diminished integration of emotion cues from faces and bodies. The result from the study shows the reverse of the proposed hypothesis. Individuals with ASD show typical integration of emotion cues from the face and body. Brewer et al. (2017) concluded that the body as a contextual cue in emotion recognition has influence on facial expression recognition in ASD, despite the use of local processing in such individuals. Therefore, in accordance with Brewer et al. (2017), I would like to explore the emotion recognition of individuals with high and low autistic traits within the neurotypical population and reach more general conclusions on the importance of facial stimuli as a contextual cue.

Aim of this study

This study investigates the relationship between autistic-related traits and emotion recognition in neurotypical university students. The aim of this study is to investigate if facial expression stimuli have an effect on body posture stimuli processing with regard to recognition of emotional expression in individuals with a broad range of autistic traits in the neurotypical population. This study hypothesised that **1)** facial expression stimuli have an effect on body posture. Specifically, we predict that an angry facial expression will lead to the recognition of anger regardless of when a participant is presented with an angry or disgusted body posture. And **2)**, the influence of facial expression on body posture in emotion recognition is correlated with autistic traits in the neurotypical population.

METHODS

Participants

Seventy undergraduate students (59 females, 11 males) at the School of Psychology from Cardiff University ranging in age from 18 and 23 years old (M = 19.74, SD = 2.62) voluntarily participated in this experiment. The participants were recruited online through Experimental Management System (EMS): an online tool that allows undergraduate students to volunteer to sign up and participate in experiments for course credit. They were granted research credits as compensation for their participation. All participants gave their digital informed consent via Qualtrics before the experiment took place. The study was approved by the School Research Ethics Committee (SREC).

Apparatus/materials

The study was conducted online through a Qualtrics survey (https://www.qualtrics.com). Participants in this research were required to complete perceptual tasks, as well as a questionnaire assessing ASD traits. In the perceptual task, participants were shown facial and bodily expression stimuli. This was used to measure how adept the participants were at discriminating emotion on the basis of different contextual information. The perceptual task stimuli were presented in Psychopy v2022.2.5 (Version 3.8; Peirce et al., 2019) and online through Pavlovia, on the participants' screen one at a time. The questionnaire task assessed ASD-related traits. The ASD-related traits were measured using the Autism-Spectrum Quotient (AQ-50; Baron-Cohen et al., 2001). The experiments were all conducted on laptop or PC.

Methodological overview

This study assessed participants' ability to distinguish between two basic emotions, anger and disgust, using a morph continuum. These emotions were selected because they both exhibit high arousal and negative valence. By measuring these emotions within the same quadrant, the study explores how context and situational factors influence their perception and processing. High arousal emotions, which involve heightened physiological responses and increased attention, can blur the distinctions between different emotions within this category. Additionally, emotions with similar negative valence can be more easily confused due to their shared unpleasant tone. In real-life situations, emotions are often experienced as blends rather than in isolation. Thus, high arousal and negative valence emotions may be interpreted interchangeably due to their overlapping characteristics. Participants were also given Autism Spectrum Quotient 50 items (AQ-50) to measure the level of autistic traits. The AQ-50 score will aid to find the correlation between the influence of facial expression on emotion recognition and the autistic traits.

Perceptual task

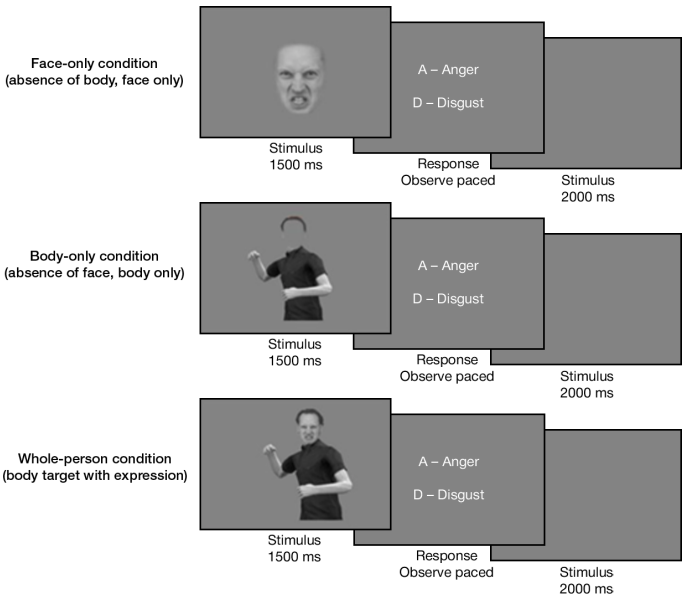
In the perceptual task, there were 3 tasks: the face-only condition task, body-only condition task, and whole-person condition task. In the face-only condition task, there were four white male identities displaying both disgust and angry facial expression from the NimStim, a series of photographs depicting actors portraying various facial expressions representing basic emotions such as happiness, sadness, anger, fear, disgust, and surprise (Tottenham et al., 2009) for eight trials in random order. Radboud Faces Database (Langner et al., 2010) were used to validate and generate the stimuli. The images of the face stimuli were presented in oval, greyscale images of faces with the absence of external information such as ears and hairs (**Figure 2**). In this task, only facial expressions of 100% anger and 100% disgust from the NimStim database were displayed in the absence of a body posture. The value corresponds to the intensity of the morph range. After the participants were shown the stimulus for 1500 ms, a response page then appeared. Participants were required to press either the "A" key on their keyboard indicating anger or the "D" key for disgust within 2000 ms or the page will show the next stimulus. This task acted as a baseline and helped to provide a measure of the facial expression recognition ability of participants.

Next, for the body-only condition, the body posture morphs were weighted averages of two motion-captured 3D body avatars expressing anger and disgust. The visualisation was carried out in the Unity 3D game engine. There were four body identities with different clothing and slightly different postures. The body morphs changed in 10% increments therefore there were a total of nine morph levels (10–90%). This morphing corresponds to the intensity of the emotion. The morphing between 100% angry and disgusted body posture from the continuum was carried out using FantaMorph Pro (Version 5). The images of the body postures were presented in grayscale with an oval window covering the facial expression (**Figure 3**). Other elements such as hair, ears and neck remained visible. Participants were required to press the "A" key for anger or the "D" key for disgust on their keyboard within 2000 ms. This task provides a measure of body posture recognition ability. There were 108 trials in face-only and body-only conditions.

In the last perceptual task, the whole-person condition presented stimuli including face and body posture. The 100% angry or fully disgusted face and the body posture obtained from the morph continuum were merged as a whole-person stimulus. Participants were required to press the "A" key for anger or "D" key for disgust on their keyboard once the stimulus was presented. Participants were required to respond

Figure 4

Three perceptual tasks on one emotion identity



Note. All tasks are counterbalanced between participants.

to the option within 2000 ms before the next stimulus appeared. These stimuli were generated in GIMP (GNU Image Manipulation Program, Version 2.10). All of the stimuli were presented as grayscale images on a grey background (**Figure 4**). All tasks are counterbalanced between participants to minimise the influence of other extraneous factors such as practice or fatigue on the experimental results. There were 216 trials in the whole-person condition where 108 trials came from body posture morph on a 100% angry face and 108 trials from body posture morph on a 100% disgusted face.

Questionnaire task

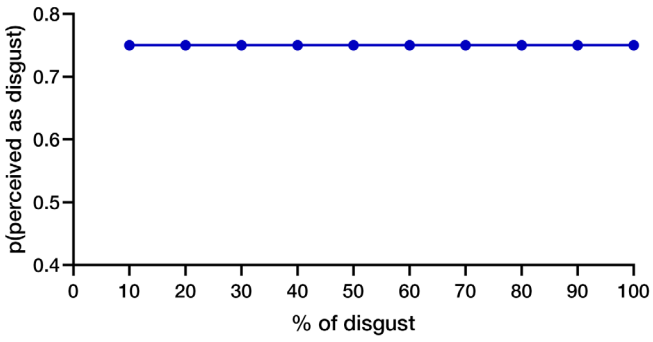
Participants were required to complete Autism-Spectrum Quotient 50 questions (AQ-50; Baron-Cohen et al., 2001). AQ-50 was used to measure the autistic traits in a neurotypical population. The higher the AQ-50 score, the more ASD traits. People with ASD have higher scores compared to the neurotypical population (Brewer et al., 2017). The exclusion cut-off point depends on the shape of the plots and the PSE slope value generated from Psychopy v2022.2.5 (Version 3.8; Peirce et al., 2019, see **Figure 5**). Participants with extreme PSE value compared to the others were excluded from the analysis. AQ-50 is a self-report questionnaire measuring five domains: Attention to detail, Attention switching, Communication, Imagination and Social skills. 24 items were normally scored (1 = Definitely Agree, Slightly Agree and 0 = Slightly Disagree, Definitely Disagree) with "agree" indicating the highest concordance with an autistic trait, and 26 were reverse-scored items (1 = Slightly Disagree, Definitely Disagree and 0 = Definitely Agree, Slightly Agree). All items were required to be answered before moving on to the debrief form.

Procedure

After giving online consent to participate via Qualtrics participants were automatically directed to Pavlovia (https://run.pavlovia.org/evondem-hagen/fb-bm_e1/html) to start the perceptual task. Before starting the task participants read the instructions. In each trial of the experiment, the participants were presented with a perceptual task first. However, the order of the tasks (face-only, body-only, whole-person) and stimuli presented within each task were randomised and counterbalanced between participants. Next, participants were automatically directed to Qualtrics to complete the AQ-50 questionnaire as part of a questionnaire task. At the end of the task, participants received a debrief about the experiment and were granted 3 course credits as participation compensation. They were also given practice trials before the start to ensure

Figure 5

Three perceptual tasks on one emotion identity



Note. An example of the slope shape that serves as the exclusion cut-off point was obtained from Psychopy v2022.2.5 (Version 3.8).

instructions were understood perfectly.

For every participant, the psychometric function for all three task conditions was obtained. Each function illustrated the percentage of disgust responses, reflecting the propensity to identify disgust cues in the stimulus presented (Brewer et al., 2017). Two main parameters can be extracted from the psychometric function: Decision noise and point of subjective equality (PSE). These two measures are important in answering the hypotheses of this study.

Decision noise can be understood as a measure of the precision of the stimuli being categorised as angry or disgusted (Brewer et al., 2017). This indicates the ability to recognise facial expressions and body postures without having any influence from the context and environment. As decision noise increases, participants' ability to discriminate between face or body postures decreases. Conversely, lower decision noise indicates that participants can perceive even small changes in stimuli in the face or body postures. Decision Noise can be calculated from the inverse of the slope obtained from the psychometric function. Therefore, the steeper the slope, the smaller the decision noise, resulting in better categorisation of anger stimuli as an angry facial expression and the disgust stimuli as disgusted facial expression.

PSE refers to the point at which participants are equally likely to identify bodily expressions as anger and disgust. The difference between the PSE value for body postures on a 100% angry face and body postures on a 100% disgusted face is a measure of the influence of facial expression on body posture perception. A larger PSE shift between the two measures reflects a larger influence of facial expression on body posture recognition (**Figure 6**).

RESULTS

Some participants were excluded from the analysis because the psychometric functions could not be modelled, as they did not engage well with the perceptual task. This could be observed from psychometric function output when the slope value is an extreme outlier from other responses or has a negative value. In the face-only condition and body-only condition, eight participants and four participants were excluded respectively from the sample. In the whole-person condition, after calculating the change in PSE, ten participants were outliers and excluded from the analysis.

The main aim of this study was to investigate if facial expression stimuli have an effect on body posture stimuli processing with regard to recognition of emotional expression. The two PSE values obtained from the PsychoPy output indicate two emotions measured (anger and disgust). Each PSE represents the stimulus intensity at which participants are equally likely to choose "anger" or "disgust" in response to the stimuli. This helps to assess potential biases in perception for different response alternatives. The data was readily available from the PsychoPy output and exported to Microsoft Excel. A paired sample *t*-test was conducted to compare the two measures of PSE 1 and PSE 2 when the body morph is at 100% angry face (**Figure 7**). There was a significant

Figure 6

The PSE of disgusted function and angry function of a participant

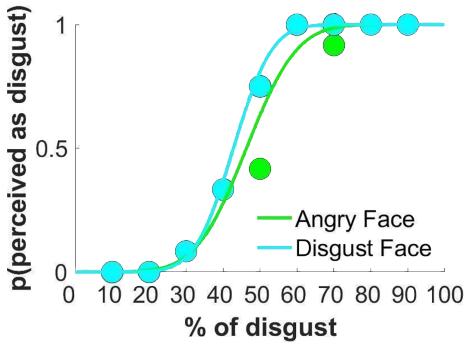
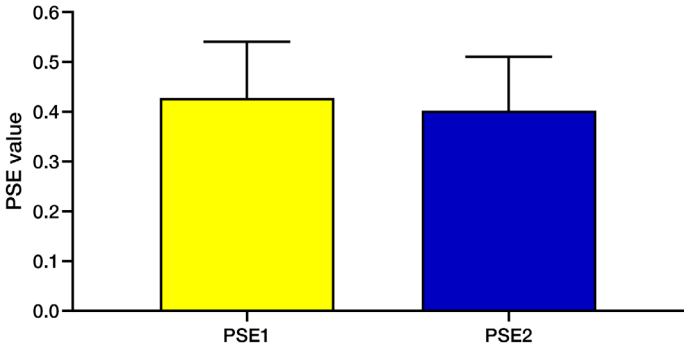


Figure 7

Mean PSE values



Note. Bar chart illustrating the mean of PSE 1 and PSE 2 when the body morph is at 100% angry face. Error bars represent the standard deviation..

difference in PSE 1 (M = 0.428, SD = 0.113) and PSE 2 (M = 0.402, SD = 0.108), where $t(59) = 2.713$, $p < 0.001$. The effect size for the difference in PSE value was calculated at Cohen's $d = 0.35$, which is considered a small to medium effect size. The finding shows that facial expression stimuli have a significant effect on the body posture as a contextual cue (refer to **Appendix E**). The high intensity of the angry facial expression stimulus made participants more likely to perceive various body postures as conveying higher levels of anger. This effect outlines how we respond to social cues in our environment.

To answer the second hypothesis, a normality test was first performed to determine if the data involved has a normally distributed population to determine the most appropriate choice of correlation coefficient. The data for the normality test is non-normally distributed, indicating that it should be treated as non-parametric data. Therefore, Spearman's rho correlation was used to carry out this analysis. The correlation was conducted between the AQ-50 score (minimum score = 3, maximum score = 43) and the PSE shift (%) of 60 participants (after exclusion). The PSE shift was obtained by finding the difference between PSE 1 and PSE 2. The value of the change in PSE was then calculated as a percentage. The results showed there was a non-significant, weak negative correlation between the AQ-50 score and the PSE shift, $r(60) = -0.155$, $p = 0.236$ (**Figure 8**). The negative correlation suggests that higher scores on the AQ-50 are associated with less influence of facial expression on body posture in the recognition of emotion.

An additional analysis was performed to provide insight into the relationship between autistic traits in relation to autistic traits measures (AQ-50) and inconsistency in decision-making. In this analysis, Spearman's rho correlation was used to analyse the total AQ-50 scores and decision noise in face-only condition and body-only condition. Examining correlations separately for the face-only and body-only conditions helps to understand if the relationship between autistic traits and decision noise differs depending on whether participants are making decisions based on facial expressions or body postures. The results show neither of the correlations showed a significant result, in face-only conditions, $r(62) = 0.069$, $p = 0.592$ and in body-only conditions, $r(66) = 0.157$, $p = 0.208$. Therefore, there is not enough evidence to conclude that individuals with higher autistic traits tend to exhibit more decision noise in their responses in both conditions.

DISCUSSION

The current study investigated the effect of facial expression on body posture recognition in the context of emotional expression in relation to autistic traits in a neurotypical population. The findings supported the first hypothesis, where facial expression stimuli have a significant effect on the recognition of the emotional states conveyed through body posture. Based on the finding, the disgusted facial expression stimuli lead to disgusted emotion recognition when presented with body postures across the intensity continuum. On the other hand, although the relationship between the AQ-50 score and the PSE shift did not reach statistical significance, the weak non-significant negative correlation suggests a potential relationship between higher autistic traits and reduced ability to discriminate between angry and disgusted expressions that may warrant further investigation with a larger sample size.

On the other hand, the result showed a non-significant weak negative correlation between the AQ-50 score and the PSE shift, indicating that participants with higher autistic traits have a slightly reduced ability to discriminate between angry and disgusted expressions compared to those with lower autistic traits.

Facial expression has a significant effect on the body posture

The results of this study suggest that facial expressions influence the perception of emotion recognition in body posture, leading to a perceptual bias. During the task, when a disgusted facial expression was paired with an angry body posture, participants tended to judge the emotion as anger compared to when it is paired with a disgusted body. This finding aligns with previous results from Teufel et al. (2019) and Hassin et al. (2013). This is what Teufel et al. (2019) refer to as a "biasing effect" (p. 141). This effect suggests that the contextual information provided by facial expressions systematically influence participants' perception of emotional expressions. In this study, the "effect" has been controlled by explicitly requesting that participants ignore the face and make judgements solely based on the body posture during the whole-person condition. This shows that facial expression and its context interplay during emotion recognition processes.

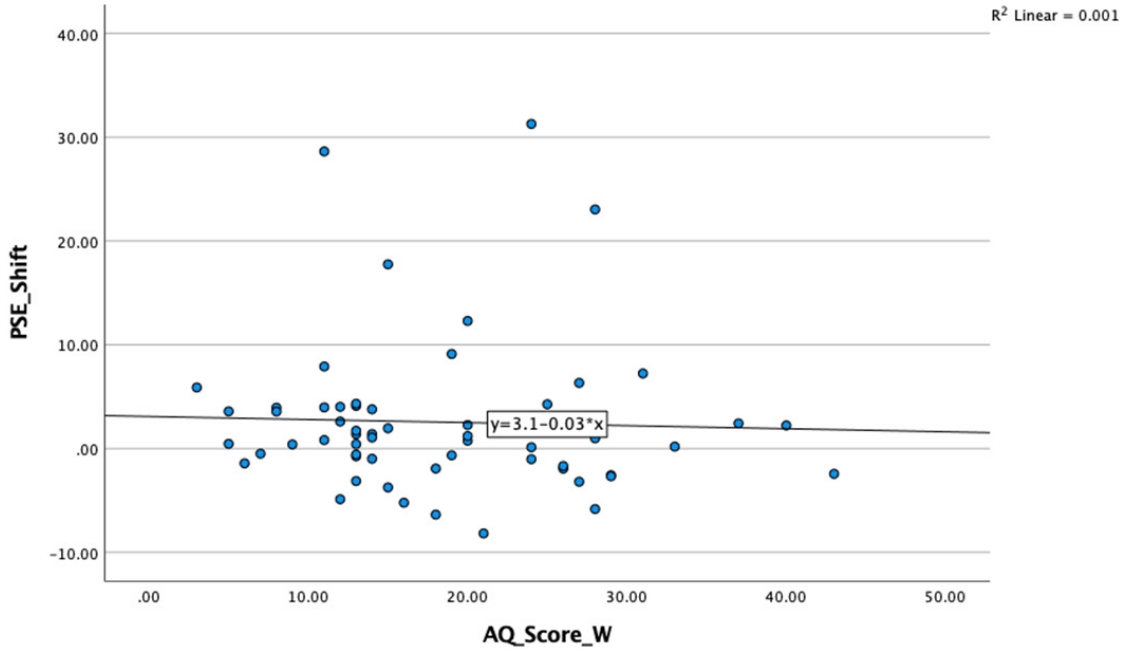
The result shows humans typically understand emotional expression by integrating cues from whole agents such as faces, postures and voice rather than treating them independently (Teufel et al., 2019). The result is also supported by the prior literature indicating that people quickly integrate emotional information from both facial expressions and body language, suggesting congruent pairs were categorised by participants more quickly and accurately than incongruent pairs (Meeren et al., 2005). They also suggested that the integration process is automatic and adaptive. Critically, this process of integration between facial and body cues occurs in early visual processing (Aviezer et al., 2008) even before the conscious awareness of stimuli reflecting global processing.

Facial expression has no effect on judgement of body morph

Next, the result from this study shows there is a weak negative non-significant correlation between the AQ-50 score and the PSE shift. This is surprising, because the study did not find a significant effect despite suggestions of a significant directional effect in previous literature (Brewer et al., 2017; Heaton et al., 2012). The higher PSE shift in this study reflects a higher influence of facial expression on body posture recognition in the whole person condition, which is expected to be seen in people with high autistic traits. However, the results obtained are not significant. This may be because of the small sample size used in this study. Notably, individuals with ASD traits have a reduced ability to interpret cues that

Figure 8

Scatter plot of AQ-50 scores vs. PSE shifts



Note. . The scatter plot illustrates the correlation between the AQ-50 score and the PSE shift.

are conveyed by facial expressions due to atypical neural processing of emotional information. This conclusion was supported by the finding of Happé (1996) that individuals with ASD traits were less likely to be influenced by, and have difficulty processing other available contexts (Wang et al., 2006). Based on **Figure 8** from the result section, we can see that participants with high AQ-50 scores exhibit a PSE shift value that is compatible with a low AQ-50 score. This further shows that individual variability in the association between AQ50 scores and PSE shifts is inconsistent across the group (Brewer et al., 2017; Harms et al., 2010).

This study also found no relationship between decision noise and autistic traits. Decision noise shows the ability of participants to discriminate facial expressions and body posture in stimuli presented. The result again shows individual variability in Decision Noise scores during the task observed from the PsychoPy output. Previous literature suggested that people with ASD are worse at discriminating facial expressions compared to the neurotypical population (Harms et al., 2010; Tanaka & Sung, 2013). Therefore, I also expected to see a significant positive correlation between the two covariables.

Moreover, limited literature also shows people with ASD are worse at interpreting body posture. De Gelder and van den Stock (2011) posited that people with ASD are less accurate in determining bodily expressive action when the facial expression is masked. Emotion recognition relies on semantic knowledge about whole body expression such as anger with a clenched fist and tensed muscle. Therefore, when body posture with 60% anger and 40% disgust (from NimStim database) is shown, the emotion is hard to be recognised, indicating that this bodily expression is ambiguous. People with autistic traits have reduced sensitivity to dynamic social stimuli in social settings due to difficulties in integrating emotional context (De Gelder & van den Stock, 2011). Therefore, a more apparent amount of disgusted expressive action is needed for discrete categorisation of disgusted emotion in these individuals. On the other hand, visual information processing also plays a crucial part in emotion recognition together with semantic knowledge mentioned in De Gelder and van den Stock (2011).

In this study, autistic traits in the neurotypical population are addressed critically to create a supportive environment that supports neurodiversity. Understanding emotional processing routes allows us to raise awareness about ASD to eliminate stigma and build inclusive environments to cater varied cognitive profiles. This approach not only improves early identification and assistance for individuals who may benefit, but it also allows for the customisation of educational and business settings to suit a wider diversity of learning and working styles. Accepting autistic traits in the general population helps to establish a more aware community, advances research to facilitate therapies and intervention for disabilities and aims to build a society that appreciates diversity and gives equal opportunity for all people, regardless of their neurodevelopmental profiles.

Overall, the present study contributes to the understanding of how facial expressions influence the recognition of the emotions conveyed through certain body postures; however, the study did not find a significant relationship between AQ-50 scores (a measure of autistic traits) and the influence of facial expression on body posture. This suggests that autistic traits may not significantly impact how facial expressions affect the recognition of the emotions conveyed through body postures.

Previous literature has shown that body posture can influence the recognition of emotions conveyed through facial expressions, but this study adds to the existing research by demonstrating that the relationship also holds in the reverse direction. These findings align with Aviezer et al.'s (2008) work, which highlighted the interplay between facial expressions and body posture cues in emotion recognition. Notably, this study focuses on ASD traits within the neurotypical population, providing valuable insights into how these traits may or may not affect the relationship between facial expressions and body posture in emotional processing.

Limitations

There are a few limitations in this study that impact the validity of the results. Firstly, the nature of the task required a minimum 40 minutes to be completed. There are 216 stimuli and a questionnaire at the end of the task. Participants could potentially start to lose focus and reduce their engagement in completing the task throughout the stimuli presentation, thus causing low accuracy in recognizing emotion and also in answering the AQ-50 questionnaire. Future research could schedule face-to-face meetings with participants and break the task into shorter segments to provide breaks, reducing the effect of fatigue.

The stimuli in this study consisted of four white male faces. To enhance the validity of future studies, it would be beneficial to include a variety of faces from different ethnicities and genders. This would

provide a more comprehensive representation of facial expressions and improve the generalisability of the findings.

The use of self-report measures for assessing the autistic traits in the neurotypical population are a further limitation of this study. Self-report measures can be very useful to assess the subjective experiences of participants; however, the reliability of the score may also be influenced by limited self-awareness causing difficulty in accurately reporting their autistic traits. Therefore, behavioural observations, physiological responses and medical history of participants can supplement self-report measures to provide a more comprehensive understanding of participants' responses.

There is also the possibility of central tendency bias, the systematic preference to choose responses around the midpoint of a scale rather than the extreme response option. This also could cause underrepresentation of variability in responses. Additionally, some psychology students are familiar with the format, structure and typical response pattern of the questionnaire due to previous exposure. This could result in a distorted or inaccurate representation of the participants' actual behaviour or attitudes, as their responses may not reflect their true beliefs or experiences. This may not be a true representation of the actual behaviour in the sample recruited. To mitigate this issue, researchers can use measures to ensure that participants are not biassed by their awareness of the questionnaire type. This could include providing clear instructions at the beginning of the study, using randomised response formats, or using questionnaires that are less likely to be influenced by central tendency bias.

CONCLUSION

In conclusion, facial expression has a significant effect on the recognition of the emotional content of body postures. People with ASD traits have reduced ability to integrate multiple inputs which causes them to face difficulty in communicating in social settings. This study is beneficial in developing social awareness among society to help build understanding around the manner in which individuals with ASD communicate, ultimately promoting a more inclusive and supportive environment to people with disabilities. Moreover, this study also is useful for the neurotypical population to understand the reduced or diminished ability of people with ASD to perceive social cues and emotional signals such as facial expressions, body language, and tone of voice in social settings.

SUPPLEMENTARY MATERIALS

Appendix

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CAMBRIDGE JOURNAL OF HUMAN BEHAVIOUR

PSYCHOLOGY

Evaluating the Efficacy of Deep Brain Stimulation and Selective Serotonin Reuptake Inhibitors as Treatments for Obsessive Compulsive Disorder

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Received February 21, 2024
Revision received September 27, 2024
Accepted October 7, 2024

Keywords:
obsessive-compulsive disorder,
selective serotonin reuptake inhibitors,
deep brain stimulation,
treatment-refractory OCD,
cortico-striatal-thalamic circuit

Obsessive-compulsive disorder (OCD) is defined through persistent obsessions and compulsions that can have debilitating impacts on the individual. The biological underpinnings have been linked to genetics, the serotonin system, and specific neural regions such as the Cortico-striatal-thalamic circuit. Various treatments have emerged to address this condition. Selective serotonin reuptake inhibitors and deep brain stimulation have shown promising results in terms of effectively treating obsessive-compulsive disorder; however, both are not without their limitations. The purpose of this article is to compare selective serotonin reuptake inhibitors and deep brain stimulation to determine the optimal treatment for OCD patients. As such the findings may be used to guide clinical procedures in future cases of OCD and may influence the treatment of other mental health conditions beyond OCD, paving the way for personalised interventions tailored to individual patients' needs.

INTRODUCTION

Obsessive-compulsive disorder (OCD) is a mental health condition characterised by obsessions and compulsions — core symptoms which can severely impact an individual and their ability to function in everyday life (Steuber & McGuire, 2023). The Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) defines obsessions as urges, images, or thoughts that are recurrent and persistent, often causing intense distress or anxiety. Compulsions are characterised as repetitive mental acts (e.g., repeating words, counting, praying) or behaviours (e.g., hand washing, checking, ordering) that the individual feels compelled to perform in an attempt to reduce the anxiety produced by their obsessive thoughts. Although, such behaviours and mental acts are often excessive or are not rationally linked to the obsessions that they are meant to neutralise. The majority of people with OCD have both obsessions and compulsions (Shavitt et al., 2014) however, due to the internal nature of the symptoms, OCD is often misidentified or unrecognised (Hirschtritt et al., 2017).

The treatment of OCD is a highly important area of research because, despite the various different methods of treatments available, not all are suitable for each individual. The condition is phenotypically heterogeneous (Bloch et al., 2008) meaning that there are a multitude of different obsessions and compulsions, therefore this could result in the efficacy of treatments being impacted by individual differences. For example, compulsions and obsessions in OCD can relate to concerns regarding contamination (resulting in washing and cleaning compulsions), concerns about symmetry (ordering and counting compulsions), concerns with potential harm to others or themself (checking compulsions, such as checking five times that a door is locked), and intrusive sexual or aggressive thoughts (resulting in mental rituals such as repetition; Stein et al., 2019). Approximately 0.8–2% of the global population have an OCD diagnosis (Ruscio et al., 2010) — at least 10–40% of these individuals will not experience symptom improvement after a full course of standard treatment, and will then develop treatment refractory OCD (TROCD) meaning their symptoms are resistant to treatment (Xu et al., 2022); however, a large proportion of people do improve with the implementation of different behavioural therapies and/or pharmacotherapy (Raviv et al., 2020; Hirschtritt et al., 2017). Hence, research into the treatment of OCD is crucial for determining the treatments with the best patient outcomes and tailoring treatments to ensure the care of all OCD patients.

At present, the most common treatment pathways for OCD consists of cognitive behavioural therapy, exposure and prevention therapy, and the prescription of selective serotonin reuptake inhibitors (SSRIs). More experimental methods include ketamine, transcranial magnetic stimulation, transcranial direct current stimulation, and, if there are no symptom improvements aftering exploring the above methods, ablative brain surgery and deep brain stimulation (DBS; Krzyszkowiak et al., 2019). The central focus of this article will be on SSRIs and DBS, ultimately aiming to determine the treatment that is most effective for OCD patients.

GENETICS AND NEUROCHEMICALS IN OCD

There have been several attempts to explain the cause of OCD through the use of biological, cognitive, and behavioural models (Krzyszkowiak et al., 2019); however, there are many theories with biological basis which will be discussed, specifically: the role of genetics, the role of serotonin, and implicated brain regions in OCD.

Twin studies have provided robust evidence regarding genetics and their contribution to OCD (Rosario-Campos et al., 2005). Twin studies have shown that monozygotic twins (MZ, i.e. identical twins) have higher concordance rates (the probability that both individuals will have a specific trait) than dizygotic twins (DZ, i.e. fraternal twins); 80–87% compared to 47–50% (McCoy et al., 2013). MZ twins have greater genetic similarity as they share 100% of their genetic variance, whereas DZ twins share only 50% of their genetic variance. Therefore, we can assume that genetics play a crucial role in the development of OCD due to the fact that MZ twins are more likely to both have OCD than it is for both DZ

twins. It should be noted that because the concordance rate for MZ twins is not 100%, it suggests that there may be environmental factors that contribute to the development of OCD. Regardless, these risk factors are beyond the scope of this essay (for further information see: Wang et al., 2023 and Yilmaz et al., 2022). Additionally, much of this research relies on the equal environments assumption (EEA) which implies that MZ and DZ twins are exposed to shared environmental factors and that twins do not experience different treatment based on their degree of genetic relatedness (Hagenbeek et al., 2023). In reality, it is likely that MZ twins may share more similar environments than DZ twins, and the higher concordance rates of MZs found in heritability studies may be caused by the higher similarity of the environment in addition to genetic similarity (Harrop et al., 2013). Therefore, violations of EEA in twin research could lead to the genetic risk being overestimated.

In addition to genetic research, there has been a significant focus on the role of serotonin in the onset of OCD symptoms. Serotonin (5-HT) is a monoamine neurotransmitter which plays a crucial role in the central nervous system as it underlies a variety of important functions such as mood regulation, behaviour, cognition, and sleep (Vanhoutte, 1990; Murphy et al., 2008). It has been proposed that OCD symptoms may be the result of a disruption in the functioning of the brain's serotonin system (Sinopoli et al., 2017; Stein et al., 2019). Individuals may inherit a dysfunction in the genetic coding for serotonergic transporters and receptors resulting in an excess of serotonin being reabsorbed into the presynaptic neuron. Maia and Cano-Colino (2015) put forward the idea that low levels of serotonin (potentially caused by dysfunctional SERT) leads to continuous neuronal activity which traps the network in a specific state, and obsessions (trends in network activity that are hard to break free from) are then caused as a result. Further support for this theory comes from the high response rates to selective serotonin reuptake inhibitors (SSRIs), which inhibits the reabsorption of serotonin in the presynaptic neuron. This has led many researchers to focus on irregular serotonergic systems as the basis of the pathophysiology of OCD (Goodman et al., 1990).

SELECTIVE SEROTONIN REPUTAKE INHIBITORS

SSRIs are the dominant choice of pharmacological treatment for OCD (Skapinakis et al., 2016). They can be effective in reducing obsessive-compulsive symptoms, are not toxic if overdosed, and have side effects that are more tolerable than other pharmacological treatments available, for example, tricyclic antidepressants (Blier & de Montigny, 1999). The mechanism underlying SSRIs is their serotonin-agonistic effect, meaning they have the opposite effect of serotonin on the synapse — blocking the reuptake of serotonin in the synaptic cleft, consequently increasing the level of serotonin activity (Xue et al., 2016). The action of SSRIs is not completely understood; however researchers have postulated a potential effect on the myelination of axons which will ultimately impact the volume of white matter in the brain (Bracco et al., 2023). Research by Koch et al. (2012) suggests differences in the integrity of white matter is correlated to the severity of ordering, and obsessing symptoms are influenced by decreased myelination; as such increased symptom severity is related to higher abnormalities in myelin. The use of SSRI treatment increases extracellular serotonin which results in the desensitisation of serotonin receptors, ultimately enhancing serotonin transmission (Sinopoli et al., 2017). Interestingly, SSRIs have an almost immediate biochemical effect at the synapse, however there is an observed delay of approximately two weeks (Marazziti et al., 2019) between the administration of the medication before the therapeutic effects are visible (Blier & de Montigny, 1999). Furthermore, despite being the initial choice of treatment for OCD, various pieces of research have highlighted that roughly one third of patients do not have any response to the medication (Blier & de Montigny, 1999), thus highlighting a need for further research and potentially the development of alternative modes of therapy. Additionally, SSRIs appear to have potential side effects which may cause individuals to stop taking them before they have had a full course of treatment or may deter individuals from taking them entirely. Side effects can include emotional blunting (also known as "reduced affect" (Marazziti et al., 2019, p. 76), essentially meaning they have reduced emotional reactivity), cognitive impairment, proneness to bone fractures, and proneness to bleeding. Cognitive side effects can include impairment of memory, attention, motivation, concentration, and emotional response to external stimuli.

There is a vast amount of research demonstrating the clinical efficacy of SSRIs, for example there are numerous randomised controlled trials (RCTs) that have shown treatments based on SSRIs are significantly more effective in reducing OCD symptoms compared to placebo treatments (Katz et al., 1990; Pittenger & Bloch, 2014). Additionally, in the study conducted by Ahmari et al. (2013), whereby mice were used to demonstrate the hyperactivation of the cortico-striatal-thalamic circuit (CSTC) and its resulting effect of heightened grooming behaviour, the researchers found that the abnormal grooming behaviours were successfully inhibited through the implementation of SSRIs, therefore demonstrating its ability to potentially reduce compulsive behaviours. Although, it is worth mentioning that long-term effectiveness of SSRIs treatment can be impacted by the presence of co-occurring disorders. Jakubovski et al. (2013) found that the addition of at least one other psychiatric diagnosis was associated with a worse treatment outcome. The lower response rates in OCD with a co-occuring disorder could be due to depressive symptoms and avoidance behaviours (both of which are common symptoms in anxiety and mood disorders, which were the most commonly co-occurring conditions in Jakubovski et al.'s sample) which may impact adherence behaviour; however this is a speculative conclusion. The prevalence of co-occurring disorders in OCD varies substantially. Research from the United States shows that co-morbid rates of major depressive disorder range from 19%–67% in adults with a primary diagnosis of OCD, with similar variation in the prevalence of other mental illnesses, such as anxiety disorders (22%–56%; Sharma et al., 2021).

In addition, a very recent review compiled brain imaging (diffusion tensor imaging, structural magnetic resonance imaging, and functional magnetic imaging) data from 7 studies and was able to identify the neural regions implicated in the reduction of OCD symptoms (Bracco et al., 2023). They established that brain differences between healthy controls and OCD patients were significantly reduced after a round of SSRI treatment (daily doses in the data ranged from 60–200 mg), specifically atypical WM volume in the region of the CSTC, corpus callosum, temporoparietal lobe, and occipital lobe appeared to normalise as a result. This evidence clearly supports the use of SSRIs and provides some explanation for the underlying mechanisms of the drugs, however there are some flaws in the research that should be acknowledged. Namely, the comparison groups used to determine the effectiveness of SSRIs were not appropriately comparable due to the use of healthy controls who had no OC symptoms, therefore preventing us from seeing the neural effects on OCD patients who didn't receive medication (Bracco et al., 2023). Therefore, precaution may be needed when considering the results of this study as it is currently unclear whether the observed improvements are the result of the SSRIs or other factors that have not been measured. A better approach may be by the use of a double-blind trial with exclusively OCD patients, wherein the symptom reduction and cortical changes could be more critically examined.

While SSRIs are the favoured treatment choice for OCD (Bracco et al., 2023), a recent meta-analysis looking into the rates of withdrawal effects from SSRIs found an average rate of 40–60% (Horowitz & Taylor 2019; Fineburg & Gale, 2005; Kim et al., 2018). Such withdrawal symptoms emulate those which the medication was originally prescribed to reduce, and such symptoms have been found to be prevalent for between two weeks and one year after discontinuation, with some evidence suggesting up to three years of symptoms (Davies et al., 2018). Moreover, the response rate to SSRI medication is significant as it means roughly half of OCD patients do not respond fully, or at all, to the best pharmacological treatment available. This may be because serotonin is not the only neurotransmitter that has been implicated in OCD, as several others (such as glutamate) have been linked to the development of the condition (Koen & Stein, 2011).

It has been proposed that the glutamate system may also be dysfunctional in OCD as research has connected glutamate transporter genes,

such as *SAPAP3* and *SLC1A1*, to the disorder (Abramowitz et al., 2009). Moreover, recent research has demonstrated that compulsive symptoms are related to the balance of glutamate and GABA in the anterior cingulate cortex (ACC) and supplementary motor area (SMA) of the frontal lobes (Biria et al., 2023). This study found that levels of glutamate in participants with OCD were significantly lower than the GABA levels in their ACC and that changes in glutamate levels in the SMA were positively related to compulsive symptoms. Therefore this suggests the balance of these neurochemicals could have a key role in OCD symptoms and thus other pharmacological treatments that target these specific neurotransmitters should be investigated.

In summary, SSRIs appear to be an effective treatment for symptom relief in most OCD patients, however, these negative consequences and response rates should not be overlooked. As a result, alternative therapies may be considered when deciding the treatment.

Neurobiological studies of OCD have determined the involvement of several brain regions in the expression of obsessive-compulsive (OC) behaviours, including the orbito-frontal cortex, anterior cingulate cortex (ACC), caudate nucleus, and the thalamus (Nakao et al., 2014), also regions known to regulate goal-directed behaviour (Kim et al., 2018). Such brain regions have been observed to have abnormally high levels of activity in patients with OCD (Nakao et al., 2014). The presentation of repetitive thoughts and behaviours are presumed to arise from dysfunctions at the subcortical and cortical levels in this neural pathway (Kalra & Swedo, 2009). Such propositions have been expanded upon to suggest that OCD may originate from disruptions within interconnected brain networks, rather than specific brain region malfunctions (Yuste, 2015). The aforementioned serotonergic genes have been linked to the presence of abnormal brain structure and function often observed in brain images from OCD patients (Mercadante et al., 2004; Milad & Raunch, 2012), primarily impacting the region known as the cortico-striatal-thalamic circuit (CSTC) — a neural circuit comprised of the orbito-frontal cortex, the caudate nucleus, and the thalamus (Alexander et al., 1986). This is supported by a review of 37 case reports investigating individuals with OCD, that developed as a result of infarctions (death of tissue) or other brain lesions (damaged area of the brain). This study found that lesions in several brain regions including the CSTC may incite compulsive behaviours (Figee et al., 2013). While brain lesions are not a common cause of OCD, the findings from these case studies provide support for the role of the cortico-striatal circuit in the pathology of OCD, and illustrate how variance within the circuit may result in compulsive symptoms in individuals who were previously healthy.

Additionally, another neural region implicated in the origin of OCD is the OCD-loop model (Saxena et al., 1998), wherein the orbitofrontal cortex projects to the caudate nucleus and the striatum, through the basal ganglia to the thalamus, before returning to the original cortical region of firing. The model has a direct and indirect pathway of activation, the former pathway resulting in an excitatory response, with the latter producing an inhibitory response (Saxena & Rauch, 2022). Studies have proposed that overactivity in the direct pathway could lead to difficulties in the suppression of repetitive behaviours (Ahmari & Dougherty, 2015; Saxena & Rauch, 2022; Ting & Feng, 2011). Additionally, an excessive amount of activity in the orbitofrontal-subcortical pathways has been observed in both people with OCD and also in mouse models that imitated OCD adjacent behaviours (Ting & Feng, 2011). Such excessive activity in these pathways has been shown to result in increased grooming behaviours, which were still maintained after stimulation stopped (Ahmari et al., 2013).

Furthermore, functional imaging literature has consistently found unusually increased activation of the medial and lateral orbitofrontal cortex (OFC; Fitzgerald et al., 2011; Menzies et al., 2008). Consistent with this, fMRI studies have demonstrated a positive correlation between lateral OFC hyperactivation and OCD symptom severity during the performance serial reaction time tasks (Rauch et al., 2007), as well as during symptom provocation (Saxena et al., 2001; Whiteside et al., 2004). Moreover, it is believed that impaired frontal inhibitory processing is associated with OFC dysfunctions, consequently resulting in increased obsessive and compulsive behaviours (Menzies et al., 2008), hence the regulation of the activity in the OFC is the neurological basis for treatment which could alleviate OCD symptoms.

The ACC stands as another key region considered to be linked to the pathology of OCD because of its involvement in error monitoring and detection, and identifying cognitive conflicts (Milad & Rauch, 2012). From cognitive task-based fMRI studies, hyperactivity in the ACC has been attributed to the mediation of flawed error signals which give rise to obsession (Fitzgerald et al., 2005; Maltby et al., 2005; Page et al., 2009). Another theory proposes that heightened activation of the dorsal ACC in OCD could mediate the increased fear and anxiety characteristic of the disorder (Pauls et al., 2014). Therefore, the reduction in ACC activity observed post-treatment indicates the key role of treatment in normalising cognitive functions or alleviating anxiety in situations triggering obsessive and compulsive symptoms.

Finally, more recent research has focused on brain matter volume and how this varies in OCD. A recent meta-analysis compared and found a significant difference between the white matter (WM) and grey matter volume (GMV) of healthy controls and OCD patients (Tao et al., 2023). In addition, the left striatum appeared to have an increase in GMV, while there was a decrease in the right hippocampus, right inferior frontal gyrus, and right superior temporal gyrus; however, it should be noted that Tao et al.'s (2023) findings contradict the results from two other large-scale meta-analyses (Kong et al., 2020; Bruin et al., 2020), which found no difference in brain structure between healthy controls and OCD patients. Nevertheless, other research has linked neurological changes to the mechanism of OCD and have suggested such changes could be key in the onset and development of the condition, as they could impact the functioning of the region. Reess et al. (2018) found significant increases in palladium volumes and decreases in hippocampus volumes in OCD patients compared to control participants. They noted that the pallidum is a core region within the CSTC circuit and that it has been assumed to be key in the mechanisms underlying obsessions and compulsions in OCD. They postulated that the decreased volume of the hippocampus in OCD may be linked to stress-related physiological processes, as is often seen in other stress-related psychiatric disorders such as depression and PTSD, speculating that high-levels of checking behaviour is associated with lower hippocampal volume levels. This is interesting as it suggests that changes at the neural level may not be the cause of OCD, some changes may occur as a result of the condition. These findings have led to the exploration of deep brain stimulation as a potential treatment for OCD.

DEEP BRAIN STIMULATION

Since the 1950s, various forms of ablative neurosurgery have been used to treat TROCD (Goodman & Alterman, 2012); however, over the last 20 years, DBS has become a promising alternative with a similar level of efficacy to ablation and the advantage of being both partially reversible and adjustable (Kohl et al., 2018; Hageman et al., 2021). DBS is an invasive method of treatment for several neuropsychiatric disorders (such as Parkinson's disease, major depressive disorder, and OCD; Malek, 2019; Graat et al., 2017) whereby an electrode is implanted into the brain, enabling the activation of neural circuits in the surrounding areas (Abramowitz, 2009). It has been proposed that the high-frequency stimulation incites "functional ablation" on the target brain structures (Goodman & Alterman, 2012, p. 515). The DBS device has four components: the stimulating lead implanted within the target area of the brain to deliver stimulation; a locking device; a pulse generator (PG), which is stationed under the skin on the chest or abdomen and supplies the current; and an extension cable connecting the PG to the power lead (Goodman & Alterman, 2012).

The majority of DBS literature focuses on white and grey matter volume in striatal areas which are involved in or have an association with the CSTC. For instance, the anterior limb of the internal capsule, subthalamic nucleus, ventral capsule/ventral striatum, nucleus of stria terminalis, and the nucleus accumbens — regions that are speculated to be important in decision-making, reward learning, and regulating mood within the CSTC circuit (Li et al., 2020; Alonso et al., 2015). The connection between such abnormal brain structures may impact the function of each brain region and therefore result in the OC presentations.

Additional evidence has shown that the areas targeted by DBS (striatal regions) are influenced by the CSTC and orbitofrontal networks and impacted pathways through these regions may be detrimental to the symptom improvement (Li et al., 2020; Bijanki et al., 2021).

Literature suggests DBS is a relatively safe and effective treatment for TROCD, with meta-analyses demonstrating an approximate symptom reduction of 50% in severe cases 24 months post-treatment. In addition, when looking at DBS for TROCD and co-occurring depression, it was reported that around half of the patients had a complete response to the treatment, while a further 16% had at least a partial response (Gadot et al., 2022). Although, it should be considered that the patients from Gadot et al.'s (2022) study were patients with co-morbid depression, implying that it cannot be determined whether the presence of another disorder had an influence on the efficacy of treatment. Nonetheless, DBS does appear to be effective in reducing OCD symptoms, with long-lasting effects, and would therefore be a better treatment than SSRIs for patients with TROCD.

Despite the clear evidence of efficacy, DBS has some limitations, some of them being quite dangerous. For instance, studies have found that there is an 8% estimated risk of hardware-related complications within the procedure and between 4.4–5% risk of infection associated with DBS (Kantzanou et al., 2021). There is additional danger as the spread of infection from the surgical site could result in meningitis, cerebritis, or brain abscesses; however, such instances are exceedingly rare and there is a high chance that these rates of infection will reduce if more surgeries are conducted and smaller components are developed (Goodman & Alterman, 2012). Moreover, the surgery for DBS is not a one-time operation as the PG is battery powered and requires replacement between 12 months and 9 years after initial implantation. The time frame for replacement is dependent on whether the PG model is rechargeable or not and the amount of current that is required to produce the optimal effect (Holland et al., 2020; Goodman & Alterman, 2012). That is to say, the patient would undergo multiple open-skull surgeries throughout their life to replace a core component of the DBS device. Such occurrence would further increase the risk of infection and surgical complications. Further, DBS is an expensive procedure which many people may struggle to pay. Based on Holland et al.'s (2020) findings, the average cost for the initial implantation of DBS hardware was $27,035 (± $3,623), while the monthly cost for some participants was $1,878 (± $1,019) until the initial battery replacement for the device. The monthly cost for impulse generator changes for participants with non-rechargeable devices was $1,517 (± $870), while the monthly cost for rechargeable devices was $654 (± $219). They also found that the average replacement of non-rechargeable batteries was every 1.4 years with an average cost of $16,432 (± $9,163). Moreover, a study conducted in the Netherlands found that the cost of DBS for two years, including the cost of the equipment, replacements, and follow-up hospital appointments, is €88,946 (Ooms et al., 2017). This was a significant cost increase as the standard treatment for two years totalled €48,330. Whilst Holland et al. (2020) found rechargeable DBS units to be more cost-effective due to minimised battery replacement cost, the DBS procedure is unlikely to be financially viable for a lot of people in countries without free healthcare, and even in countries with free healthcare services, the treatment would be a large financial strain on such services (i.e., the NHS in the UK).

To summarise, DBS is an effective alternative treatment for OCD patients who have developed treatment-refractory symptoms; however, considering the cost and the risks of DBS, this treatment should only be a last resort option if patients do not respond to standard SSRI treatment or other available treatments.

CONCLUSION

SSRIs are the most common treatment for OCD (Skapinakis et al., 2016) and have demonstrated high rates of efficacy for short-term usage (Pittenger & Bloch, 2014). Despite this, they have limitations such as withdrawal symptoms, emotional blunting, cognitive impairment, bone fractures, and excessive bleeding, and have little to no effect for some patients (Marazziti et al., 2019). Whereas DBS is a more experimental treatment and comes with many long-term surgical risks and hardware complications (Kantzanou et al., 2021), research has shown that it is an effective alternative for treatment refractory individuals with long lasting effects (Gadot et al., 2022). Accordingly, there are several factors that must be considered when attempting to treat each case of OCD: the severity of the patient's symptoms, the cost and availability of the treatments (particularly for individuals where healthcare is not free or subsidised), and the potential risks of the treatment. Therefore, for each OCD patient, an individualistic approach must be taken as the most effective mode of care will be dependent on the specific pathogenesis and presentation of each OCD patient. As research continues to advance, we may see additional treatment options emerge, further expanding the possibilities for managing OCD.

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CAMBRIDGE JOURNAL OF HUMAN BEHAVIOUR

BIOLOGICAL ANTHROPOLOGY

Trabecular Bone Response Variation in the Hominoid Clavicle

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Received September 21, 2023
Revision received June 27, 2024
Accepted July 5, 2024

Keywords:
cancellous bone,
functional morphology,
hominoid,
Homo sapiens,
trabecular bone

Previous studies have identified substantial variations in trabecular bone structure at regions of soft tissue attachment (entheses) and joint surfaces. However, the different effects of tensile and compressive forces on trabecular microarchitecture have remained largely unexplored. This study turns attention to such forces within the clavicle, a bone subjected to both compressive and tensile loading, to compare trabecular microstructure in these distinct loading environments. Using micro-CT scans of adult hominoid clavicles of several distinct genera, we measured trabecular thickness (Tb.Th), trabecular separation (Tb.Sp), and trabecular number (Tb.N) across the entire element. Our findings reveal nuanced differences in trabecular bone structure between entheses and subarticular surfaces. Entheses achieve higher density by increasing trabecular separation and trabecular thickness, while subarticular surfaces achieve it through higher trabecular number, and decreased trabecular thickness and trabecular separation. Notably, the joint region exhibited a higher trabecular number and lower trabecular separation, indicative of response to compressive forces. Conversely, at muscular entheses, a decrease in trabecular number alongside increased trabecular thickness, countered by higher trabecular separation, suggested a contrasting structural arrangement. These discernible variations likely correlate with diverse adaptations in muscle placements on the clavicle, significantly influencing the nuanced biomechanics and distinctive locomotor behaviours observed across primate species (Crane et al., 2019).

INTRODUCTION

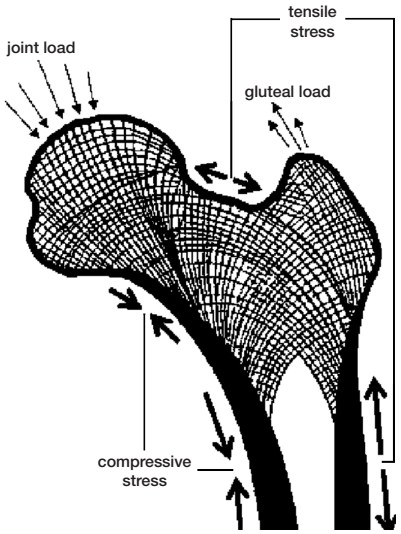
Trabecular bone, an essential component of the skeletal system, plays a pivotal role in resisting mechanical forces and maintaining skeletal integrity (Kivell et al., 2016, see **Figure 1**). Previous investigations into trabecular bone structure have demonstrated obvious variations at regions of soft tissue attachment (Biewener et al., 1996), known as entheses, and at joint surfaces (Barak et al., 2011; Crane et al., 2019). While certain aspects of external bone shape can be influenced by factors like the boundaries of muscle attachments or joint articulations, their reliability in inferring behaviour has been a subject of debate among researchers. Despite some studies suggesting a potential correlation between bone shape and behaviour, scepticism persists regarding the accuracy of using these skeletal markers to infer locomotive regime (Kivell, 2016). More recently, examining trabecular bone (spongy material that occupies the epiphysis and metaphysis of most bones) alongside external morphology has emerged as a critical piece of the paleoanthropological investigation into the evolution of locomotive behaviour.

To delve deeper into this complex terrain, it is crucial to consider the broader context of trabecular bone structure. For instance, an increased bone volume fraction (BV/TV) has been a focal point in trabecular bone research due to its relevance in understanding bone strength and resistance to mechanical stress (Mori et al., 1997; Georgiou et al., 2019); however, achieving increased BV/TV (calculated bone volume/total volume per voxel) involves intricate combinations of various trabecular parameters, such as trabecular thickness, number, and separation. This study aims to explore the nuanced mechanisms behind increases in trabecular bone density, specifically the role of these parameters furthering our understanding of the functional significance of internal bone structure. Specifically, on the measurement of three critical trabecular parameters: trabecular thickness, trabecular separation, and trabecular number across the clavicle. Understanding parameters of morphology contributes directly to the understanding of the specimens studied (humans, chimpanzees, gorillas) and indirectly can be informative of morphological behaviour across the hominin clade (Tsegai et al., 2013; Voisin, 2006).

Generally regarded as a "neglected bone" (Voisin, 2006, p. 944), the clavicle serves as a critical component of the shoulder girdle, and as such reflects the forces applied in locomotion. Muscular groups relevant to the clavicle's function include the pectoralis major, vital for arm flexion initiation, especially in humans (Gagey, 1985), and the deltoid, whose primary function is in arm abduction in obligate bipedal genera. For other apes, clavicular shape and curvature may allude to the necessity of powerful arm elevation (Voisin, 2006), but the trabecular structure underlying the enthesis[1] may provide more insight into their use. For tree dwellers, a more extensive response from the deltoid may reflect in the microstructure due to brachiation[2]; for knuckle walkers, this would be unnecessary. In examining trabecular behaviour in these entheses, recent studies suggest that the properties of trabecular bone under multiaxial loading could depend more on individual struts than the overall structure, a factor potentially relevant to understanding the clavicle's adaptive responses (Januddi et al., 2020; Pontzer et al., 2006). Furthermore, the ability of trabecular bone to rapidly remodel throughout life

Figure 1

Cross-sectional view of a femur, delineating its internal composition



Note. This femur exhibits two fundamental components: cortical bone, constituting the outer shell, and trabecular bone, situated in the inner region. The cortical layer, displayed as a dense, continuous structure, encompasses the femur's outer surface, adept at bearing and distributing compressive forces efficiently. In contrast, the inner region showcases the trabecular bone, featuring a lattice-like pattern. This porous structure within the femur provides flexibility and resilience, crucial for adapting to varying mechanical demands. Notably, the figure highlights the responses of trabecular bone to different mechanical stresses. Arrows denote the specialised adaptations of cortical and trabecular bone to distinct mechanical (tensile and compressive) stresses, portraying their synergistic role in maintaining the femur's structural integrity and functionality during weight-bearing activities.

offers valuable insights into an individual's behaviour and joint posture under predominant stress (Tsegai et al., 2013); however, relative to our understanding of external morphology, the mechanisms by which trabecular bone senses and responds to strains, particularly tension, remain elusive (Pontzer, 2006). Despite insights from tissue engineering studies which suggest that trabecular struts may be particularly responsive to such tensile strains (Crane et al., 2019), gaps remain in our understanding of the specific mechanisms governing the remodelling of trabecular bone and its precise structural relationship to bone strength (Goulet et al., 1994; Mori et al., 1997; Georgiou et al., 2019).

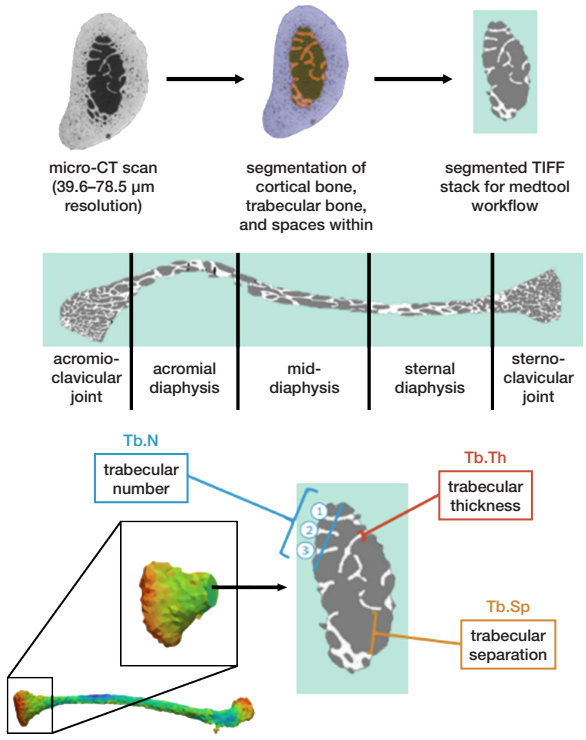
Comparing samples from gorillas, chimpanzees and humans is essential in understanding variation in trabecular bone adaptation throughout the hominoid lineage. This variation is related to differences in modes of locomotion: *Gorilla* sheds light on terrestrial knuckle-walking adaptations; *Homo* illustrates the stability of obligate bipeds; *Pan* demonstrates agility in arboreal and terrestrial settings (Tsegai et al., 2013). The predictive capacity of locomotor biomechanics in deducing the behavioural patterns and posture of last common ancestors among hominoids, hominines, and hominins can be supported in this study of the internal morphology of the clavicle. Common understanding (Larson, 1998) attributes physical characteristics of the these living genera's trunk and upper limbs with bipedality. These characteristics include a rigid lumbar spine, a wide and flattened rib cage integrating the spine ventrally, a correspondingly broad pelvis, a rearward-positioned scapula attached to the rib cage, and a shoulder joint facilitating extensive abduction (Crompton, 2008; Larson, 1998). In exploring trabecular response patterns in the clavicle, these trabecular parameters (which are indicative of locomotion unique to each genera) offer valuable insight into the role of evolutionary adaptations within the shoulder complex (Georgiou et al., 2019).

MATERIALS AND METHODS

Micro-CT scans of 31 adult, wild-origin hominoid clavicles (*Gorilla gorilla*, *Pan troglodytes*, *Homo sapiens*; **Table 1**) were obtained and analysed using the medtool 4.5 software (v. 4.5; www.dr-pahr.at/medtool).

Figure 2

Diagram of the process to obtain trabecular number, separation, and thickness from the segmented scans of each specimen



Note. The clavicle was divided into five sections (acromioclavicular joint, acromial diaphysis, mid-diaphysis, sternal diaphysis, and sternoclavicular joint), with each section analysed for the three parameters listed above. Generally defined as the number of trabeculae per unit length, trabecular number (Tb.N) is calculated as the inverse of the mean spacing between the midlines of the trabeculae. The metric of trabecular thickness (Tb.Th) is calculated in this work as the mean trabecular bone diameter derived from the segmented trabeculae. Trabecular separation (Tb.Sp) is defined as the primary diameter of the cavities containing bone marrow, calculated here as the mean spacing between the edges of segmented trabeculae.

The specimens used for this study originate from the Cleveland Museum of Natural History (CMNH), Field Museum of Natural History (FMNH), and American Museum of Natural History. All non-human apes are of wild-origin, with their collection locality specified in museum records. Human clavicles were sampled from the Hamann-Todd Collection (HTH) at the Cleveland Museum of Natural History. This collection comprises over 3,000 individuals who died in Cleveland, Ohio between 1893 and 1938 and most of those in the collection come from Ohio's public institutions such as hospitals, poorhouses, and prisons (Williams & Ross, 2021). Despite these individuals having been legally accumulated at the time of the collection's conception, the legislation, at the time, was a part of a societal framework that restricted the consent of those involved. Trabecular thickness, trabecular spacing, and trabecular number (**Figure 2**) were measured across the entire clavicle, employing a multiple volume of interest approach.

Micro-CT scans were obtained at the University of Chicago utilising a Phoenix Nanotom (180–240 kV) and V|tome|x (350–400 kV) combination, a high-resolution CT scanner. Scans were conducted with a resolution ranging between 60.106 to 89.203 microns. CT scan data were manually segmented to delineate the medullary cavity space and the trabecular bone structure it encompasses (**Figure 2**). This segmentation process was carried out using Avizo Lite (v. 2020.2, Thermo Fisher), resulting in meticulously defined TIFF stacks. The segmented TIFF stacks served as the primary input for subsequent analysis using medtool 4.5. For quantitative comparison, the clavicles were divided into five regions of interest; acromioclavicular joint, acromial diaphysis, mid-diaphysis, sternal diaphysis, and sternoclavicular joint (**Figure 2**). A multiple volume of interest approach (described further in Tsegai et al.

Table 1

Taxon, sex, number, and locomotive regime by genus

Taxon	*N*; wild/captive	Locomotive regime	Sex
Gorilla gorilla	*N* = 10; all captive (FMNH)	Quadrupedal knuckle walking	5 M, 5 F
Pan troglodytes	*N* = 13; all captive (FMNH)	Bipedal and quadrupedal	8 M, 5 F
Homo sapiens (anatomically modern)	*N* = 8; all anatomically modern (CMNH HTH collection)	Bipedal	1 M, 7 F

2013) was then used to quantify trabecular thickness (Tb.Th), trabecular separation (Tb.Sp), and trabecular number (Tb.N)) within each of the defined regions (**Figure 2**).

RESULTS

Across these three hominoid taxa, the subarticular trabecular bone displayed higher trabecular number and lower trabecular separation (**Figure 3**). Additionally, the sternal end displayed an even higher trabecular number and lower trabecular separation than the acromial end. Consistent repetitive microfracturing from compressive force may be responsible for the higher trabecular number in joints (see **Discussion**).

Generally, regions of muscular and ligament attachments display visible differences in trabecular density (e.g. Ryan & Shaw, 2013; Tsegai et al. 2013; Skinner et al. 2015), and the work here showed that this is achieved through a combination of increased trabecular separation and trabecular thickness. This heightened thickness appears to be a response to the loading environment created by the tensile forces generated by attaching muscles and ligaments, effectively reinforcing the cortical structure during periods of increased muscular activity. Separation may represent a response to strut reorientation in an anisotropic (directional) reaction to tension. This aligns with Saers et al. (2022) in findings concerning trabecular growth patterns post-initial ossification: trabecular bone, which first forms orthogonal to the growth plate and ossifies into a dense, anisotropic structure, undergoes remodelling by removing elements that experience minimal loading. This captures the idea that increased separation is based on resorption of unneeded (unstressed) trabeculae, while trabeculae thicken in response to locomotive stress.

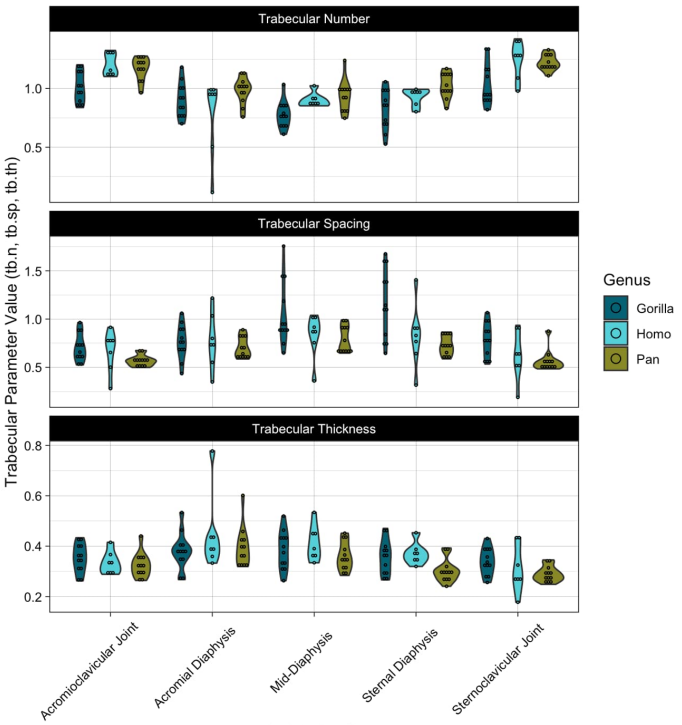
When looking at genus-based comparisons, the most intraspecific species differences across all three factors — trabecular thickness, trabecular separation, and trabecular number — were evident in *Gorilla*. This distinction was not solely attributed to inherent variability but was also further examined by sex (as depicted in **Figure 4**). Moreover, within the clavicle, gorillas exhibited notably higher values in trabecular thickness along the mid to sternal diaphysis in comparison to chimpanzees and humans. Gorillas displayed marginally greater trabecular separation in the acromial diaphysis region compared to chimpanzees and humans. Conversely, chimpanzees exhibited relatively higher trabecular number in the acromial diaphysis compared to both humans and gorillas.

DISCUSSION

The higher trabecular number and lower trabecular separation (**Figure 3**), coupled with decreased trabecular thickness, may be indicative of a reaction to compression in line with microfracturing for repair mechanisms in a partial volume effect (Hernandez et. al, 2005). Areas of higher separation and thickness may reflect reaction to tensile forces with thicker, more distanced and oriented struts (Best et. al, 2017). This combination strongly suggests that subarticular trabecular bone is exceptionally well-suited to withstand and absorb compressive forces frequently encountered at joint surfaces (Goulet et al., 1994). Additionally, the sternal end displayed an even higher trabecular number and lower trabecular separation than the acromial end. Consistent repetitive microfracturing from compressive forces may be responsible for the higher trabecular number in joints.

Figure 3

Findings across three hominoid taxa concerning subarticular trabecular bone



Note. Notably, the joint region exhibits a higher trabecular number and lower trabecular separation, indicating exceptional resilience to compressive force. Conversely, at entheses, sites where muscles and ligaments attach, decreased trabecular number and increased trabecular thickness oppose a higher Tb.Sp.

Based on the trabecular structure, the sternal end may be subjected to heightened compressive loading at the sternoclavicular joint, whereas the acromial end may undergo greater tensile loading, particularly during activities involving suspension and vertical climbing.

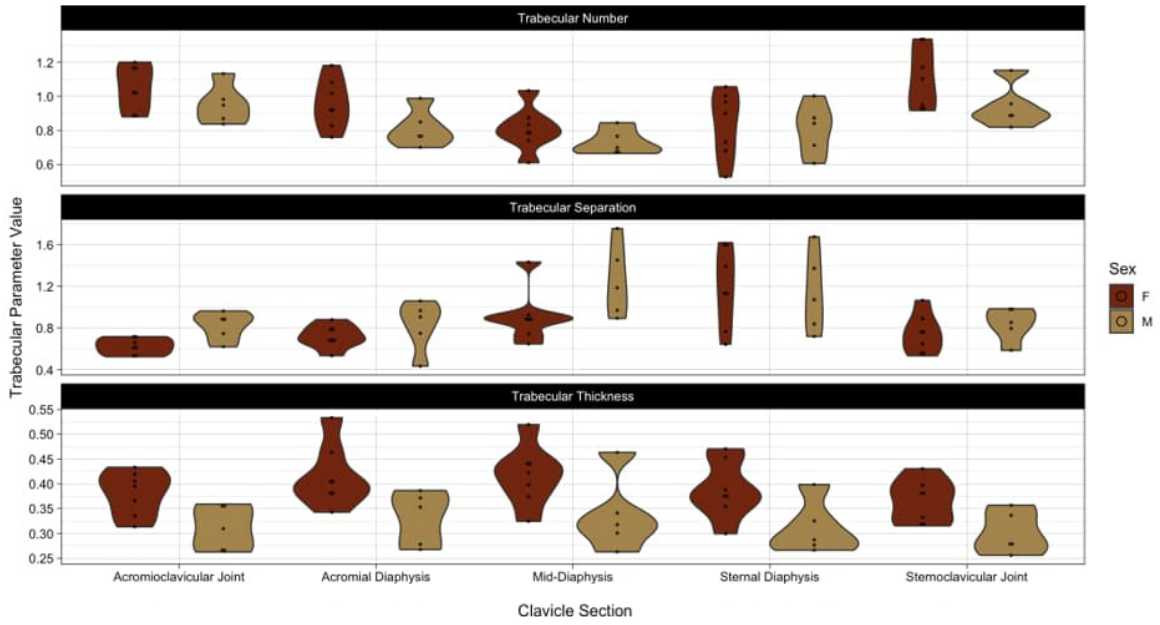
Of significance is the unique location of the pectoralis major (and deltoid) insertion on the clavicle found in humans (see **Appendix**) and chimpanzees, a feature which distinguishes these genera from *Gorilla* (Potau et al., 2018; Ashon & Oxnard, 1963). This distinct insertion pattern may influence arm flexion dynamics, as demonstrated in humans and gibbons (Gagey, 1985; Stern et al., 1980). The associated action of the pectoralis major, coupled with the internal curvature (ventrally/anteriorly projecting) of the clavicle acting as a "crank", facilitates the rotation of the glenoid cavity of the scapula. Variations in this curvature could potentially impact the efficiency of such muscular actions (Gagey, 1985; Stern et al., 1980).

For the variation in the acromial end, one could attribute the chimpanzee clavicular deviation to deltoid insertions — which set chimpanzees apart from gorillas and humans in their assistance with more arboreal behaviours such as brachiation (Voisin, 2006). The majority of the deltoid muscle attachment is located on the cranial surface of the acromial end in chimps while it is more on the ventral/anterior in *Homo* (see **Appendix**). While the muscular insertions on the clavicle may not explicitly indicate differences in locomotor behaviour, they likely reflect adaptations to similar forces (Stern et al., 1980). This notion aligns with observed differences between tree-dwelling and ground-dwelling primates. For instance, *Gorilla spp.* less frequently inhabit trees, which may result in less pronounced arm elevation, resulting in a clavicle with a diminished internal curvature (Voisin, 2006).

Voisin and Balzeau (2004) further highlighted disparities in the arrangement of bony structures within the clavicle among humans, chimpanzees, and gorillas, indicating heightened resistance in the chimpanzee clavicle compared to its human counterpart. This underscores the potential influence of clavicle morphology on force distribution and, consequently, locomotion within each primate species.

Figure 4

Variability within Gorilla *separated by sex*



Note. Due to the dramatic difference between *Gorilla* male and female specimens relative to chimpanzees and humans, a separate graph was made to illustrate the distinction. The factor observing most variation was thickness, finding males on average 0.1 units of thickness less than females.

The observed variations in trabecular bone microstructure may be associated with these diverse adaptations in muscle placements on the clavicle, contributing to the nuanced biomechanics and distinct locomotor behaviours evident across different primate species.

The differences in trabecular bone microstructure among gorillas, chimpanzees, and humans are intricately linked to unique muscular attachments on the clavicle, influencing arm flexion dynamics and scapular rotation (Gagey, 1985; Stern et al., 1980). These adaptations, coupled with variations in clavicular morphology and bony structures, underscore the potential influence of muscle placements on the clavicle, shaping nuanced biomechanics and diverse locomotor behaviours among primate species (Voisin & Balzeau, 2004; Voisin, 2006).

In further investigations, a valuable path for research may include study of the microarchitecture involved in these responses, such as the specific forces and directions implicated in catastrophic bone failure (Crane et al., 2019). While this study primarily delved into understanding medial-to-lateral variations in bone modelling, remodelling, and overall organisation, acknowledging the complex nature of observed fracture patterns is crucial. Factors such as bone mineral density stand among numerous elements that could substantially contribute to these patterns (Andermahr et al., 2007).

CONCLUSION

Ultimately, the findings underscore the importance of employing internal morphological assessments to decipher the intricate relationship between clavicle morphology, internal microarchitectural response, and locomotor behaviours. Developing a more robust understanding of the mechanisms underlying subarticular response will not only improve the theoretical framework behind study of Hominoidea (and therefore the broader evolution of locomotive behaviour and anatomy), it can contribute to the wider context of bone mechanics. The intricate relationship between bone microstructure and mechanical loading holds crucial implications for the prevention and treatment of skeletal disorders, including osteoporosis. The complexities of bone response and elasticity are studied as distinct combinations of trabecular parameters, which underscore the nuanced nature of bone modelling in response to different mechanical loading environments. To better develop strategies for medical treatment, methodologies for understanding osteological response to muscular loading, and for the broader study of palaeoanthropology, it is imperative to understand the intricacies of interaction between these parameters. Trabecular number, separation, and thickness hold great significance in the wider discussion of trabecular bone morphology and how it contributes to understanding locomotive behaviour. Additionally, the potential utilisation of trabecular assessments in scrutinising fossil primate and hominoid clavicles offers invaluable insights into the evolutionary changes within the shoulder complex, opening promising avenues for further comprehending the adaptations and biomechanical dynamics of the clavicle across evolutionary timescales.

NOTES

1. "Enthesis" refers to any insertion of connective tissue to a bone, including tendons, ligaments, fascia, and joints.
2. "Brachiation" refers to the action of swinging using only one's arms.

SUPPLEMENTARY MATERIALS

Appendix

Article references

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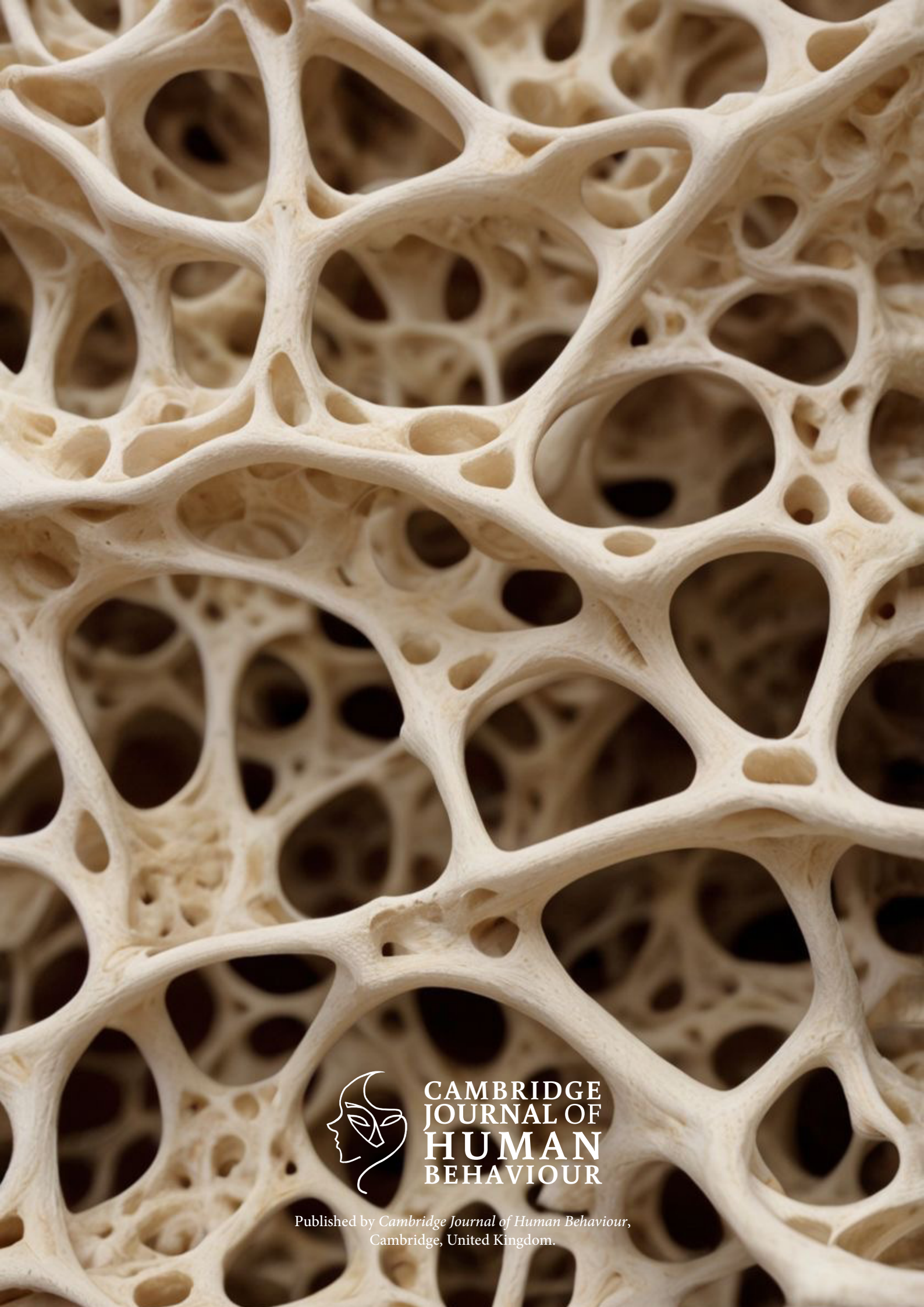

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