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Single Case Report

Experimentally-evidenced personality alterations following meningioma resection: A case report

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ABSTRACT

Personality changes following neurosurgical procedures remain poorly understood and pose a major concern for patients, rendering a strong need for predictive biomarkers. Here we report a case of a female patient in her 40s who underwent resection of a large sagittal sinus meningioma with bilateral extension, including resection and ligation of the superior sagittal sinus, that resulted in borderline personality disorder. Importantly, we captured clinically-observed personality changes in a series of experiments assessing self-other voice discrimination, one of the experimental markers for self-consciousness. In all experiments, the patient consistently confused self- and other voices – i.e., she misattributed other-voice stimuli to herself and self-voice stimuli to others. Moreover, the electroencephalogram (EEG) microstate, that was in healthy participants observed when hearing their own voice, in this patient occurred for other-voice stimuli. We hypothesize that the patient's personality alterations resulted from a gradual development of a venous collateral hemodynamic network that impacted venous drainage of brain areas associated with self-consciousness. In addition, resection and ligation of the superior sagittal sinus significantly aggravated personality alterations through postoperative decompensation of a direct

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frontal lobe compression. Experimentally mirroring clinical observations, these findings are of high relevance for developing biomarkers of post-surgical personality alterations.

1. Introduction

Fear of post-operative changes in personality and the sense of self remains a major source of distress for patients undergoing a neurosurgical procedure (Schaller et al., 2021). Lacking adequate protocols, neurosurgeons are unable to assess the likelihood of such outcomes. As both their frequency and circumstances remain largely unknown, there is a strong need for documented reports of post-surgical personality changes.

Personality alterations following brain damage have intrigued neuroscientists and clinicians ever since the famous case of Phineas Gage (Harlow, 1868), whose personality changed following a tamping iron accident. Changes in personality have also been reported following traumatic brain injury (Franulic et al., 2009; Norup & Mortensen, 2015; Prigatano, 1992; Yeates et al., 2008), tumor resection (Barrash et al., 2020; Jenkins et al., 2016), and deep brain stimulation (Pham et al., 2015). However, different reports often differently define the term ‘personality’, and changes in personality are typically assessed using subjective measures, such as interviews and questionnaires, which are prone to well-known participant and experimenter biases (Adler, 1973; Rosenthal & Fode, 1963). Here, we explored whether a clinically-diagnosed personality change could be mirrored in an experimental paradigm associated with the sense of self, thereby avoiding such biases and allowing for a standardized comparison to healthy participants both in terms of behavioral performance and task-associated neuroimaging.

Sense of self has become one the key interests in recent neuroscience research, potentially opening the door to the expertise necessary to bridge the aforementioned clinical gap. Namely, there has been an increase of experimental paradigms developed to assess various aspects of self-consciousness. Broadly, such paradigms could be divided in two categories (Gallagher, 2000) – those related to the bodily aspects of the self (Blanke, 2012; Blanke et al., 2015; Park & Blanke, 2019), such as multisensory and sensorimotor integration, and those related to cognitive aspects (Feinberg & Keenan, 2005; Northoff et al., 2006; Qin et al., 2020), such as language, memory, or recognition of self-related cues. Combining those paradigms with neuroimaging enables to pinpoint brain areas that scaffold the sense of self, thereby serving as potential candidates related to post-operative personality alterations. They often include insular, medial prefrontal, cingulate, medial prefrontal, and inferior frontal cortices, as well as temporo-parietal junction (Blanke et al., 2015; Legrand & Ruby, 2009; Northoff et al., 2006; Park & Blanke, 2019; Scalabrini et al., 2021). Compared to healthy controls, patients often perform differently in experimental paradigms assessing the sense of self (Bassolino et al., 2019; Bernasconi et al., 2021; Betka et al., 2022; Candini et al., 2018; Schaller et al., 2021; Shergill et al., 2005; Whitford, 2019), which might be indicative of a blurred self-other boundary in certain pathologies. For instance, inability to distinguish self from other has long been related to some psychiatric symptoms, such as passivity sensations and auditory-verbal hallucinations (i.e., ‘hearing voices’) (Ford & Mathalon, 2005; Frith et al., 2000; Moseley et al., 2013; Shergill et al., 2005; Whitford, 2019).

One such paradigm is our self-other voice discrimination (SOVD) task (Orepic et al., 2023), that belongs to the second category and enables to draw a perceptual boundary between self and other in the auditory domain. With our SOVD task, we are able to pinpoint individual perceptual specificities related to auditory self-other boundary (Orepic et al., 2021, 2022, 2023), such as impairments in general self-other discriminability, inability to recognize only self/other voice (e.g., self-specific impairments), or a bias to hear self/other voice. Moreover, we identified a self-voice specific electroencephalogram (EEG) microstate, at mean latency 345 msec, during SOVD in healthy population (Iannotti et al., 2021) that activates a brain network involving insula, cingulate cortex, and medial temporal lobe structures. This microstate occurs more often when participants hear self-voice, compared to hearing other voices, and this correlates with SOVD task performance. Thus, assessing SOVD and the corresponding neural activity in patients might serve as a biomarker of pathological alterations in the sense of self, including post-surgical personality alterations.

Here, we report a case of a patient who experienced a significant personality change that was significantly intensified following a neurosurgical procedure, and eventually resulted in a diagnosis of borderline personality disorder. Importantly, performance in the aforementioned SOVD task was concordant with her neuropsychological and psychiatric reports. Specifically, the patient reported hearing her own voice when, in fact, she was presented with the voices of others, and vice versa – she reported hearing her voice when presented with other-voice stimuli. Remarkably, the behavior opposite to healthy participants was even corroborated in task-related EEG findings – the neural pattern observed in healthy participants associated with self-voice (Iannotti et al., 2021), was observed in this patient with other-voice stimuli. In the sections below, we summarize her clinical image and describe behavioral as well as neuroimaging analyses and results. The chronological timeline of the described events is outlined on Fig. 1.

2. Neurosurgical procedures

In 2014, the patient (44 years old at the time, university-level education) underwent a bi-frontoparietal craniotomy for the resection of a large superior sagittal sinus (SSS) meningioma with bilateral extension, including resection and ligation of the SSS. Preoperative Magnetic Resonance Imaging (MRI) showed a left frontal 5 × 4 cm extra-axial lesion invading the anterior portion of the superior sagittal sinus (Fig. 2A). An

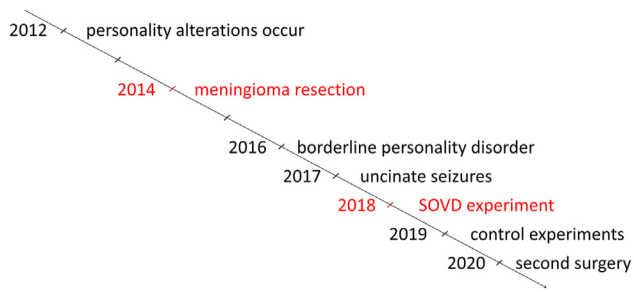

Fig. 1 – Timeline outlining patient's medical history and experimentation.

electroencephalogram performed prior to the surgery did not reveal any pathological findings. The surgical removal of the lesion Simpson IV underwent without any complications. No new focal neurological deficit could be observed at the post-operative time. The final diagnostic revealed a transitional meningioma WHO I. The postoperative MRI showed a small residual tumoral tissue at the posterior superior portion of the resection cavity (Fig. 2B). The yearly MRI showed no recurrence of the meningioma and indicated a stability of the small remnant until five years after surgery, in which the remnant appeared larger (Fig. 2C). A second surgery was performed in 2020, and the recurrent meningioma could be removed without complication. No new focal neurological deficit was observed.

The main reason why residual tumor was left behind is that the tumor extension was beyond the SSS, and only a minority of such tumors may be resected with Simpson Grade 0 (Aguiar et al., 2022). It cannot be clarified with certainty that the small remnant that was left behind at the junction between a cortical vein and the SSS may have caused the (small) recurrence, because meningiomas may crawl through the different dural layers in general, and in that region, the complex multilayered anatomy of the wall of the SSS. Thus, a gross total resection may not be possible always, in view of goal mentioned above: preservation of anastomosing and cortical veins whenever possible, so as to maintain existing relevant (yet not clinically assessable) collateral flow.

There were no signs of venous infarction, other than post-operative edema in left F2. It is not possible to observe the effect of venous hypertension alone (i.e., partially occlusive hyperemia without stagnation-perfusion breakthrough and tissue destruction) on the MRI venography images (Supplementary Fig. 5).

3. Neuropsychological and psychiatric evaluations

In 2012 (at the age of 42), two years prior to meningioma resection (i.e., the first surgery), the patient started complaining about experiencing changes in "personality" and "behavior", without being able to specify the causes of those changes. Clinical investigations identified polymorphic psychiatric symptomatology characterized by atypical anorexic behaviors, emotional dysregulation with episodic self-damaging behaviors, panic attacks, and periodical alcohol abuse. She also reported sensory disturbances in the form of paresthesias along her right leg and dysesthesias along her right index finger that would disappear after 24 h. Physical exams did not show any pathological signs, in particular no sensory deficits.

The neuropsychological exams prior to surgery did not report anything pathological, apart from an increase in anxiety, likely due to the proximity of the surgery. Indeed, the slight decline in certain verbal tests did not lead to poor scores and had no impact on spontaneous language; the limited inhibition capacities seemed to refer more to a personality component than to an executive deficit. On the behavioral level, neuropsychologists observed strong anxiety, as well as numerous complaints about the current mood, e.g., reports of the patient complaining about "not really understanding her psychological functioning anymore". No psychometric test formally assessing mood states was carried out before the 2014 operation. During the 2 years before the surgery (2012–2014), the patient followed psychoanalytic psychotherapy provided by a psychologist, 2 sessions per week, and occasionally met a psychiatrist who prescribed oxazepam 15 mg on a regular basis and escitalopram 5 mg (for 2 months, October–November 2013, only).

After the removal of meningioma, mood fluctuations were more frequent and more intense, the quality of sleep degraded, anxiety levels were higher, and depressive traits appeared, accompanied with suicidal thoughts. This was not addressed with formal psychometric evaluation, but based on physicians' clinical observations. As time went by, her psychological disturbances worsened and emotional liability increased. The patient had two isolated psychotic episodes with complex and non-malevolent multisensory hallucinations, accompanied by presence hallucinations. In 2016, psychiatric evaluation reported an **International Classification of Diseases**, Tenth Revision (ICD-10) diagnosis of organic emotionally labile (asthenic) disorder (F06.6) and emotionally unstable personality disorder, borderline type (F60.31). F06.6 related the diagnosis to the lesional effect of the meningioma. Following the surgery, the patient also developed symptoms resembling the Gastaut-Geschwind syndrome – a hypergraphia, marked hyposexuality, and an increased interest in subjects related to spirituality – that were absent throughout his previous life. A clinical neurological examination carried out 3 years later reported a temporal epilepsy manifested with uncinate seizures, that could partially account for these symptoms (Devinsky & Schachter, 2009; Tebartz van Elst et al., 2003).

In 2022 and upon our request, the patient's husband and daughter filled in the Iowa Scales of Personality Change (ISPC), a questionnaire developed to assess personality disturbances following brain damage (Barrash et al., 2011) that has been specifically related to personality changes following meningioma resection (Barrash et al., 2020). It consists of a series of items that reflect different personality characteristics and fall under predefined dimensions of personality alterations: Executive Deficits, Disturbed Social Behavior, Diminished Motivation/Hypo-Emotionality, Emotional Reactivity, and Distress (Barrash et al., 2011). The items are rated by people close to the patient and scaled from 1 to 7, separately for patient's behavior before and after brain damage. The items in which both the husband's and the daughter's reports were overlapping and concordant are the following: irritability

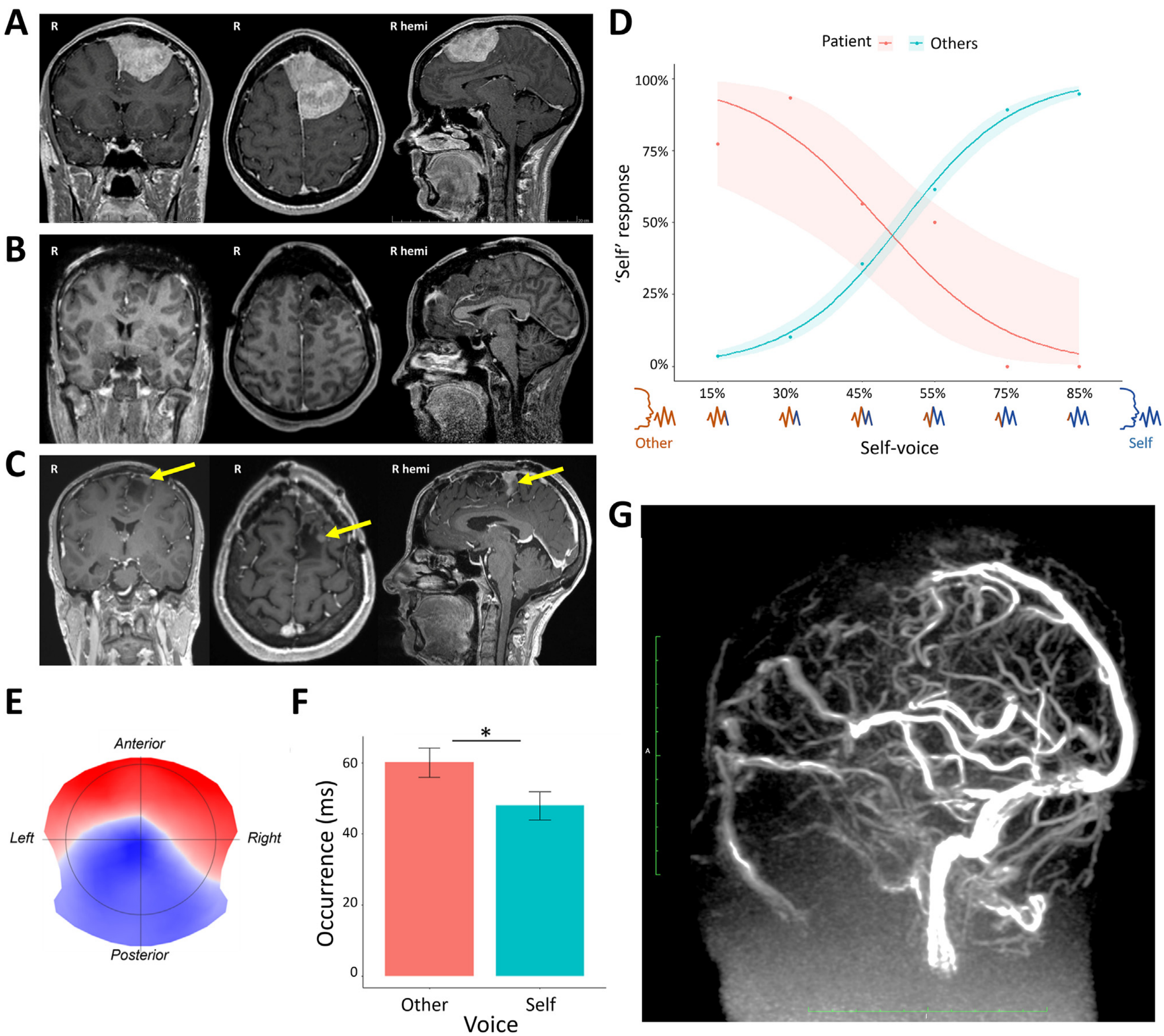

Fig. 2 — A) Preoperative structural MRI. B) Postoperative MRI. C) A subsequent MRI (1-year follow-up) indicating a residual of the meningioma (yellow arrow). D) Psychometric curves fitted for patients' performance in self-other voice discrimination (SOVD) task. Contrary to all other patients (cyan), this patient (red) inverted self- and other voices. The shaded areas around each curve represent the 95% confidence intervals. E) Patient's microstate specific for the SOVD task. F) Occurrence of patient's SOVD microstate is higher for Other-voice stimuli. Bar plots indicate mean occurrence for each voice and whiskers indicate standard error. G) Preoperative MR venography of the patient, lateral view. The anterior part of the superior sagittal sinus is occluded. There are extensive venous collaterals anterior and posterior to the occlusion site.

(score before/now: increased), lack of initiative (score before/now: reduced), moodiness (score before/now: increased), lack of stamina (score before/now: reduced), social withdrawal (score before/now: reduced). They reflect changes in the following dimensions of personality disturbances: Emotional Reactivity (irritability, moodiness), Executive Deficit (lack of initiative), Diminished Motivation/Hypo-Emotionality (social withdrawal). Lack of stamina is considered a standalone change not falling under any of the proposed dimensions (Barrash et al., 2011). ISPC findings highlight the emotional aspects of personality, which is in accordance with the ICD-10 diagnoses.

4. Self-voice experiments

In 2018, the patient participated in our SOVD experiment. She belonged to a cohort of 24 patients that were recruited to assess and quantify the effects of surgical resection of various brain regions (Supplementary material) on potential changes in self-consciousness with carefully designed experimental paradigms (Schaller et al., 2021).

In the SOVD task (Iannotti et al., 2021; Orepic et al., 2021, 2022, 2023), participants are asked to identify the dominant voice (self or other) in ambiguous self-other voice morphs.

Specifically, patient's voice (vocalization/a/with the duration of 500 msec) was morphed with a voice of a gender-matched unfamiliar voice, generating voice morphs that contained different ratios of patient's voice (e.g., a voice morph could contain 40% of patient's voice and 60% of an unfamiliar voice). The patient heard six different voice morphs (containing 15%, 30%, 45%, 55%, 70%, and 85% of her voice), each repeated 50 times in a random order, and was instructed to indicate, by clicking on a button, whether the voice she heard more resembled her voice or someone else's. Patient's voice was recorded while vocalizing phoneme/a/for approximately 1–2 sec with Zoom H6 Handy recorder. Voice stimuli were normalized for duration (500 ms) and average intensity (−12 dBFS) and cleaned from background noise (Audacity software, 12 dB, sensitivity: 6, smoothing: 3 bands). The morphing was done in TANDEM STRAIGHT software (Kawahara et al., 2013).

Cyan psychometric curve on Fig. 2D indicates average behavior of all other patients, indicating a typical increase in 'self' responses (y axis) with the increase of self-voice ratio present in voice morphs (x axis). The red curve, that of this patient, has a negative slope, indicating that the patient inverted self- and other voices (i.e., she was responding 'self' for other-dominant voice morphs, and vice versa). Similar absolute values of the slopes of the curves (this patient: 83.4%, other patients: mean = 80.6%, SD = 6.9%) indicate that the patient could indeed discriminate the two voices, but nevertheless misattributed them.

In order to investigate whether the observed self-other confusion was specific to this task, on a second visit (in 2019), we performed three additional control tasks that involved no voice morphing (i.e., 100% or 0% self-voice). In all tasks, the same /a/ vocalizations were used in total of 20 counterbalanced trials, presented in a randomized order. In the first task (Supplementary Fig. 1A), the patient heard both unmorphed voices (self and other) one after another, and was instructed to indicate which of the two voices was her voice, by pressing a button. In all 20 trials, the patient inverted the voices (i.e., responded 'self' for other-voice stimuli, and vice versa). In the second task (Supplementary Fig. 1B), the patient heard one voice per trial (self or other) and was instructed to indicate whether it was her voice. Again, in all 20 trials, the patient inverted the 2 voices. Finally, in the third task (Supplementary Fig. 1C), the patient was instructed to say /a/ for approximately 1 sec, after which one voice (self or other) was immediately presented to her. When the stimuli were presented directly after speaking, the inversion rate was reduced – in 16 out of 20 trials (80%). Interestingly, in all the trials in the third task in which the patient was correct, she heard self-voice stimuli, indicating that speaking prior to the stimulus presentation increased accuracy only for the actual own voice, and not misattributed other voice. This shows that the present effects were not specific to our SOVD task but extend to other self-voice recognition paradigms.

5. EEG analysis and results

We recorded and analyzed high density EEG during the SOVD task in the manner equivalent to our previous work on healthy participants (Iannotti et al., 2021). EEG preprocessing included filtering between [1–40 Hz], removal of artifacts (eye-blinking, saccades, ballistocardiogram, motion), reduction to 204 electrodes and interpolation of artefacted channels. Event-related potentials (ERPs) were defined for each voice morph, by selecting EEG epochs between −50 and 500 ms around the stimulus onset. In order to increase the number of the epochs and the signal-to-noise ratio, we averaged Self-dominant (containing 85% and 70% self-voice) and Other-dominant voice morphs (15% and 30% self-voice).

EEG microstate segmentation (Brunet et al., 2011; Murray et al., 2008) was performed by considering the Other- and Self-dominant ERPs. This process allowed to delineate the sequence of scalp EEG topographies or microstates reflecting the brain states that are functionally stable in time. To assess the statistical difference between Other- and Self-dominant morphs, we 'fitted back' each obtained microstate (Supplementary Fig. 2) across the single ERPs associated with the two experimental conditions. Substantially, the fitting procedure assesses the spatial correlation between each microstate and the ERPs, by labeling each ERP time-point with the microstate showing the highest correlation value. In output, the fitting procedure gives the values of a set of parameters describing, among others, the power and time characteristics of each microstate along the ERPs. For each of the fitting parameters and each microstate, a paired t-test was therefore used to define the statistically significant difference between Self- and Other-dominant voice morphs.

In healthy participants (Iannotti et al., 2021), we identified a SOVD-specific microstate that activated a brain network involving insula, cingulate cortex, and medial temporal lobe structures, at mean latency of 345 ms. This microstate occurred more often when healthy participants heard self-voice, compared to hearing other voices, and it correlated with SOVD task performance. In the patient, this microstate (Fig. 2E) occurred more often [$t(96) = 2.31$, $p = .023$] for Other- (mean = 60.06, SD = 39.94) compared to Self-dominant (mean = 47.9, SD = 38.96) voice morphs (Fig. 1F).

In order to link patient's EEG results to our previous EEG findings on healthy participants during the equivalent SOVD task (Iannotti et al., 2021), we evaluated the spatial similarity (i.e., spatial correlation of the scalp voltage potentials) between the set of patient's microstates and the set of healthy participants' microstates. The highest spatial correlation (.9, Supplementary Fig. 3) was observed between patient's microstate 7 (Supplementary Fig. 2B and main Fig. 2E) and healthy participants' microstate 4 (Iannotti et al., 2021). Importantly, for patient's microstate 7, an inverted pattern in respect to healthy subjects' microstate 4 was observed. Specifically, the occurrence of microstate 4 in healthy participants was significantly higher in Self-dominant compared to Other-dominant voice morphs (Iannotti et al., 2021) while the opposite was observed for patient's microstate 7 (main Fig. 2F).

The neuronal sources associated with patient's microstates were estimated by using the same electrical source imaging (ESI) approach of our previous work (Iannotti et al., 2021), by considering the patient's post-operative MRI. We restricted the visualization to the top 10th percentile of the normalized distribution (between 0 and 1) of activation values across all brain. The ESI revealed that patient's SOVD-associated microstate 7 was associated with right-hemispheric lateralization, contralateral to the resected lesion. Two major hubs were located in the frontal and temporal lobe (Supplementary Fig. 4), with maximal activation in the right Inferior frontal gyrus (rIFG), opercular part.

6. Discussion

Harmoniously joining expertise from neurosurgery, psychiatry, and neuroscience, here we report personality alterations following a neurosurgical procedure that were reflected in a sensitive experimental paradigm. Borderline personality disorder that occurred following superior sagittal sinus (SSS) meningioma resection was reflected both in patient's behavioral performance as well as in EEG patterns during a self-other voice discrimination (SOVD) task.

The main contribution of this work, compared to previous reports of post-surgical personality alterations is that we related personality changes to an experimental paradigm and the associated brain activity, as compared to measures based on subjective reports. Using subjective measures can not only bias the measurements (Adler, 1973; Rosenthal & Fode, 1963), but also lead to a misinterpretation of the findings over time. The extent of this can be evidenced in how much the story of Phineas Gage has evolved over 150 years (Macmillan, 2000). We tested a paradigm with established behavioral and EEG patterns in healthy participants (Iannotti et al., 2021; Orepic et al., 2023) in a patient with a borderline personality disorder. First, the use of psychophysics in our paradigm allowed us to quantify the extent of other-to-self misattribution. Second, we observed that the EEG pattern that is in healthy participants associated to the self, in this patient occurred for non-self stimuli (misattributed as self). These changes reflect the clinically-observed 'shift away from the self'.

ICD-10 F06.6 diagnosis associated personality alterations to the lesional effect of the meningioma, thereby raising the question of how could the SSS resection have impacted the neural basis of personality. Tumor site is known to impact the type of post-operative behavioral change. Changes in personality, affective processing, and social cognition were mostly associated with frontal tumors (Avery, 1971; Barrash et al., 2020; Filley & Kleinschmidt-DeMasters, 1995; Jenkins et al., 2014), whereas temporal tumors were associated changes in memory and occurrence of hallucinations (Evers & Ellger, 2004; Filley & Kleinschmidt-DeMasters, 1995; Horrax, 1923). Rather than focusing on isolated brain areas associated with personality [e.g., ventromedial prefrontal cortex (Abel et al., 2016; Barrash et al., 2020)], we propose that SSS resection might have impacted several interconnected networks that play a role in the neural mechanisms underlying the sense of self. Specifically, we hypothesize that, in this patient, personality changes result from the compressive and venous occlusive effects of the meningioma. Following gradual occlusion of the superior sagittal sinus by the meningioma, a large venous collateral network has developed (Fig. 2G), affecting the direction and the pathways of venous drainage (Brito et al., 2019). In this patient, that has concerned both frontal lobes due to the anterior sagittal sinus infiltration (Mantovani et al., 2014; Raza et al., 2010), which might have accounted for the development of pre-surgical personality alterations. With resection of the sinus and possible compromise of some collateral pathways and/or change of venous flow-direction, regional venous overload or alteration of regional blood flow may have impacted personality-related brain regions. This might have contributed to the sudden increase of the personality alterations after the surgery. Gradual occlusion and subsequent resection of anterior sagittal sinus could thus account for the gradual appearance of personality alterations prior to surgery, that were significantly increased following the resection.

Though, from a purely neurosurgical point of view that risky surgery went well, with no new postoperative neurological deficits noted, a more generalized or remote effect may be postulated. The aforementioned hypothesis is further corroborated by the delayed onset of temporal lobe epilepsy in this patient. The preoperative sensible interplay between a personality-relevant psychiatric disposition (borderline personality) and meningioma-related structural alteration of the frontal lobes and cerebral venous drainage decompensated through the open resection of the tumor and the infiltrated venous sinus.

In addition to the intellectual attempt to relating a neurosurgical action with a specific psychiatric consequence, these findings have important implications for the understanding of the brain mechanisms underlying the sense of self, which cannot be faked by the examined person in a systematic manner. First, our data relate a low-level perceptual feature – self-other voice confusion – to a higher-level deficit – borderline personality disorder, indicating phenomenological interrelatedness between different hierarchical aspects associated with the sense of the self (Blanke et al., 2015; Canzoneri et al., 2016; Northoff et al., 2006). Second, observing that brain areas associated with self-voice and the sense of self more generally [e.g., right insula (Iannotti et al., 2021; Ronchi et al., 2015; Scalabrini et al., 2021)] were in this patient associated with other-voice stimuli suggests that they might not necessarily encode the actual self-related stimuli (e.g., physical self-voice), but our subjective attribution of those stimuli. For instance, two neuroimaging studies (Kaplan et al., 2008; Nakamura et al., 2001) associated rIFG activity with hearing a physical self-voice while, in our patient, rIFG activity was associated with a voice subjectively attributed to the self, that physically belonged to another person. Potentially, one might assume that in this and related pathologies, brain activations traditionally associated with the self might be observed for any type of stimuli (e.g., faces or body parts) subjectively attributed to the self. Future studies should demonstrate that the present effects generalize to modalities other than auditory.

This approach could be extended to psychiatric phenomena other than personality disorders. For instance, it has long been proposed that auditory-verbal hallucinations (AVH) – hearing voices with speakers absent – might arise as a deficit in SOVD, where internal self-vocalizations are misattributed to someone else (Ford & Mathalon, 2005; Frith, 1987; Frith et al., 2000; Moseley et al., 2013; Shergill et al., 2005; Whitford, 2019). Exposing voice-hearers to SOVD task and relating the corresponding SOVD microstate to the underlying behavior might thus either significantly support or challenge this prominent account.

A limitation of this work is that we do not have an assessment of SOVD prior to the removal of meningioma, that could be compared to the observed post-surgical SOVD. According to our assumption relating SOVD to personality alterations, we would observe diminished SOVD inversion effects before the resection. However, present findings still make a strong case for that claim, considering that out of 24 tested patients only this patient inverted self and other voices, and that only in this patient we observed significant personality alterations associated with the resection.

It should also be noted that self-voice stimuli were presented through air conduction, rendering the sound of self-voice somewhat unnatural. Namely, during natural speech, there is also the component of bone conduction, which makes our voice sound deeper to us (Orepic et al., 2023). Indeed, in our previous work with healthy participants (Iannotti et al., 2021; Orepic et al., 2023), we showed that presenting self-voice stimuli through bone conduction improves self-other voice discrimination, as compared to air conduction. However, this does not mean that it is not possible to recognize our voice also through air conduction. Namely, as we (Iannotti et al., 2021; Orepic et al., 2023) and others before us (Allen et al., 2005; Candini et al., 2014; Conde et al., 2015; Rosa et al., 2008) have shown, even though air-conducted self-voices are less ecological, participants are able to recognize their voice also in air-conducted stimuli. Moreover, and central to this work, we also showed that in the same SOVD task used here, analogous brain mechanisms are activated both through air and bone conduction (Iannotti et al., 2021). In this work, we related those brain mechanisms, which were associated with self-voice in healthy participants both through air- and bone-conduction stimuli, to the brain mechanisms observed in patient (only with air conduction).

To conclude, here we report that major personality alterations which occurred following a resection of a large sagittal sinus meningioma can be evidenced in a SOVD task, thereby paving the way for development of novel biomarkers for the sense of self that could be used for pre- and post-surgical evaluation.

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CRediT statement

Pavo Orepic: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization.

Giannina Rita Iannotti: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization.

Julien Haemmerli: Investigation, Writing – Original Draft, Writing – Review & Editing.

Cristina Goga: Investigation, Writing – Review & Editing.

Hyeong-Dong Park: Conceptualization, Investigation, Writing – Review & Editing.

Sophie Betka: Investigation, Writing – Review & Editing.

Olaf Blanke: Conceptualization, Resources, Supervision, Project administration, Funding acquisition, Writing – Review & Editing.

Christoph M. Michel: Conceptualization, Resources, Supervision, Project administration, Funding acquisition, Writing – Review & Editing.

Guido Bondolfi: Investigation, Writing – Original Draft, Writing – Review & Editing.

Karl Schaller: Conceptualization, Resources, Supervision, Project administration, Funding acquisition, Writing – Review & Editing.

Transparency and openness promotion

The conditions of our ethics approval do not permit public archiving of anonymized study data. Readers seeking access to the data should contact the lead author Giannina Rita Iannotti or the local ethics committee at the Department of Medicine, University of Geneva. Access will be granted to named individuals in accordance with ethical procedures governing the reuse of sensitive data. Specifically, requestors must meet the following conditions to obtain the data: completion of a formal data sharing agreement, and a separate consent form signed by the patient.

Examples of experimental stimuli and scripts can be found on the following Open Science Framework (OSF) repository: https://osf.io/uxvh7/. This repository refers to a study in which the same experiment was performed on healthy participants.

EEG analysis was done in CARTOOL (Murray et al., 2008), which is an open-source GUI-based software: https://sites.google.com/site/cartoolcommunity/home. Therefore, no analysis code was used.

No part of the study procedures or analyses was pre-registered prior to the research being conducted. We report how we determined our sample size, all data exclusions (if any), all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study.

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Patient consent statement

The patient signed a consent form related to this publication on June 10th 2022.

Declaration of competing interest

The authors have no competing interests to declare.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cortex.2023.08.006.

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