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A putative implication for fronto-parietal connectivity in out-of-body experiences

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ABSTRACT

Self-processing has been related to the prefrontal cortex (PFC) and the temporo-parietal junction (TPJ) as well as to their connectivity. So far, out-of-body experiences (OBEs), impressive transient deviations of intact bodily self-integration, could be associated with the TPJ, but the mediation by the frontal lobe, and thus fronto-parietal connectivity, is yet unknown. Thus, we assessed switching performance to assess fronto-parietal connectivity when healthy participants [11 reported previous OBEs (OBE-individuals); 36 reported no previous OBEs (nOBE-individuals)] performed two different mental own body imagery tasks. By using the same stimuli of a front-facing and back-facing human figure, a cue simultaneously presented with the target indicated to participants whether they had to take the position of the depicted human figure (disembodied self-location mimicking an OBE) or had to imagine that the figure was their own reflection in a mirror (embodied Self-location). By repeating trials of the same task instruction for a differing number of trials (2–6 trials), we could assess switch costs when alternating between these two task instructions with switch costs being considered to be a behavioural indicator of fronto-parietal connectivity. Results showed that OBE-individuals performed worse than nOBE-individuals in switch trials, but not in trials in which the same task instruction was repeated. Moreover, this reduced performance was specific to body positions that are normally considered easier (front-facing in the mirror condition; back-facing in the OBE mimicking condition). These findings suggest that a fronto-parietal network might be implicated in OBEs, and that the flexible and spontaneous egocentric perspective taking of self-congruent body representations is hampered in individuals with previous OBEs.

1. Introduction

Intact self representation relies on the ability to experience oneself as an enduring and spatial entity (i.e., the feeling that we are the same person across time and space) to which certain mental events and actions are ascribed (i.e., the feeling of agency; being author of one's own thoughts and actions) and which is distinct from the environment (e.g., Blanke et al., 2005; Brugger et al., 1997; Frith, 2005; Halligan, 2002; Kircher and David, 2003; Ramachandran and Hirstein, 1998 for recent accounts). More recent philosophical and neurological theories have also highlighted the relevance of the bodily self, i.e.,

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the non-conceptual representation and processing of body-related information (Gallagher et al., 2000; Metzinger, 2003; Legrand, 2007).

Neuroscientific studies showed that the prefrontal cortex (PFC) and the temporo-parietal junction (TPJ) are importantly implicated in self-processing. For instance, functional magnetic resonance imaging studies revealed PFC and TPJ activation when healthy participants performed social and cognitive perspective taking tasks (e.g., theory of mind, ToM) (e.g., Fletcher et al., 1995; Gallagher et al., 2000; Saxe and Wexler, 2005; Vollm et al., 2006). Studies that investigated the neural correlates of the feeling of agency also point to the implication of the PFC (Vinogradov et al., 2006) or the TPJ (Farrer et al., 2004). Support for the role of the PFC and/or the TPJ in such self-processing tasks is also supported by findings from patients with focal brain lesions (Apperly et al., 2004).

With respect to the interplay between the PFC and the TPJ, it has been suggested that the PFC might hold different perspectives in working memory (e.g., Gallagher and Frith, 2003), inhibit the interference from one's own (as compared to another) perspective (Ruby and Decety, 2003), and might be important in executive response selection (Behrendt, 2004). The TPJ might be relevant to mental state reasoning in general (Saxe and Kanwisher, 2003), or to lower level sensory processing of relevant stimuli (Allison et al., 2000; Frith and Frith, 1999). Recent studies by Apperly et al. (2004) and Saxe and Wexler (2005) would, however, suggest that the TPJ is crucially involved in ToM reasoning. Together, it could be assumed that intact self-processing might rely on an intact dynamic information flow in fronto-parietal networks.

Self-processing is impaired in patients with schizophrenia, in particular when individuals suffer from passivity symptoms (e.g., thought intrusion, loss of agency, alien delusions). Thus, deficient self-processing in these patients has been found in ToM tasks (Frith and Corcoran, 1996; Schenkel et al., 2005), empathy tasks (Langdon et al., 2006), and agency tasks (e.g., Farrer et al., 2004; Lindner et al., 2005; Spence et al., 1997). With respect to implicated brain regions, self-processing deficits in these patients have been associated with the PFC and the TPJ (Brunet-Gouet and Decety, 2006 for review; see also Farrer et al., 2004; Spence et al., 1997). Recent studies using diffusion tensor imaging support the notions (Friston, 1998) that patients with schizophrenia show abnormalities in cortico-cortical as well as cortico-subcortical connectivity (as measured by white matter integrity), whether in the early illness onset (Federspiel et al., 2006; Hao et al., 2006) or in the more chronic state (Honey et al., 2005; Nestor et al., 2004). Also, patients with schizotypal personality disorder as compared to controls reveal altered fronto-temporal connectivity (Nakamura et al., 2005). In sum, findings from healthy participants, neurological populations and patients along the schizophrenia spectrum would suggest that self-processing relates to both the PFC and the TPJ, and that impaired self representations might relate to a disconnection between these brain sites.

Given the importance of the PFC and the TPJ (and thus their connectivity) in self-processing such as agency, ToM, and perspective taking, one might hypothesize that PFC and its connectivity to the TPJ is also implicated in out-of-body experiences (OBEs). OBEs are impressive disturbances of self representation characterized by disembodiment, altered visuo-spatial perspective and agency and have primarily been linked to the TPJ (see below) although they might also follow damage to frontal cortex (Devinsky et al., 1989). OBEs are transient and highly vivid, presumably of paroxysmal nature (Blanke et al., 2004; Blanke et al., 2005; Blanke et al., 2002). More specifically, during an OBE, the individual has the transient impression that the self is detached from the physical body, and that the world and the own physical body is seen from an elevated spatial position (Blanke and Mohr, 2005 for recent review). Findings from neurological populations would link OBEs with TPJ damage (Blanke et al., 2004; Blanke et al., 2005; Blanke et al., 2002; Brandt et al., 2005).

Because OBEs are rare and occur spontaneously (Blackmore, 1982), testing a priori the potential role of the PFC in OBEs seems almost impossible. Recent reports, however, not only suggested that brain processes during the mental transformation of one's own body might engage some similar brain mechanisms as those activated during spontaneous OBEs (Blackmore, 1982; Brugger, 2002; Cook and Irwin, 1983), but also provided empirical evidence for this claim (Blanke et al., 2005). In more detail, Blanke et al. (2005), performed an event-related potential (ERP) study and a transcranial magnetic stimulation (TMS) study with healthy participants as well as depth-electrode recordings and continuous surface EEG recordings from a patient with epilepsy. The ERP study showed the selective activation of the TPJ at 330–400 msec after stimulus onset (see also Arzy et al., 2007) when healthy volunteers imagined themselves in the position and visual perspective that is generally reported by people experiencing spontaneous OBEs (OBT-task, see Section 2 for further details). The TMS study showed that interference with the TPJ by TMS during this same time period impaired performance in the OBT-task in healthy volunteers relative to TMS over a control site at the intraparietal sulcus. No such inference was observed for imagined spatial transformations of external objects suggesting the selective implication of the TPJ in mental imagery of one' own body. With respect to the last part of this report, the epileptic patient, when experiencing OBEs, revealed seizure activity at surface electrode positions around the TPJ. When performing the OBT-task, ERPs from subdural electrodes showed task-specific activation at the TPJ. Together, these results by Blanke et al. (2005) suggest that the TPJ is a crucial structure for the conscious experience of the normal self mediating spatial unity of self and body.

In order to test the fronto-parietal mediation of OBEs neuropsychologically, we here made use of a modified version of the OBT-task (Arzy et al., 2007; Arzy et al., 2006; Blanke et al., 2005; Mohr et al., 2006): we asked individuals with previous OBEs (OBE-individuals) and those without previous OBEs (nOBE-individuals) to switch continuously between the OBT-task (Arzy et al., 2007; Blanke et al., 2005; Mohr et al., 2006), and between another egocentric mental perspective taking condition (Arzy et al., 2006), in which the same stimuli were shown, but in which participants were required to imagine that the depicted human figure was the reflection of their body in a mirror (Mirror-task). Both tasks can be suggested to target the ''body schema'' (Coslett, 1998; Parsons, 1994), but to differ in the egocentric frame of reference (Zacks and Michelon, 2005) with the OBT-task relying probably more strongly on an ''extrinsic egocentric coordinate system'' and the Mirror-task on an ''intrinsic egocentric coordinate system'' (e.g., Buxbaum et al., 2000; Shenton et al., 2004). Support for a dissociation between tasks has been provided by Arzy et al. (2006) who found that brain activity during the Mirror-task dissociated from brain activity during the OBT-task temporally (earlier task-related brain activation during the Mirror-task) and anatomically (both tasks activated lateral temporo-occipital cortex and TJP, but the TPJ was more strongly recruited in the OBT-task and the lateral temporo-occipital cortex more strongly in the Mirror-task). Thus, by using these two task instructions while keeping the visual input constant, we would predict that OBE-individuals, due to their potentially compromised brain network related to the OBT-task (Blanke et al., 2005), would show inferior performance (slower responding, lower accuracy) when switching between these two tasks as compared to the nOBE-individuals.

The switching component can be considered sensitive to fronto-parietal connectivity, because task switching has been shown to rely on the executive control of the PFC, whether conclusions are drawn from behavioral studies on brain-damaged patients (Kumada and Humphreys, 2006; Milner, 1963; Stuss and Benson, 1986), non-human primates (Mansouri et al., 2006; Miller and Cohen, 2001), or from brain-imaging studies (Brass and von Cramon, 2002; Passingham et al., 2000). It has also been shown that the PFC appears to act in concert with the parietal cortex (Chafee and Goldman-Rakic, 1998; Dove et al., 2000; Ruge et al., 2005). Information flow might be directed from frontal cortex to parietal cortex with the former involved in action execution and the latter in the processing of stimulus properties (Ruge et al., 2005). While both processes might be relevant to switching trials (SwT) and trials in which the same task is performed as in the preceding trial (repeat trials, RepT), this fronto-parietal network might be under higher challenge in the former than the latter case (Ruge et al., 2005). Thus, in case that OBEs might also be mediated by the PFC, we here predicted that switching between the two tasks would result in higher switch costs in OBE-individuals as compared to nOBE-individuals.

2. Methods

2.1. Participants

Forty-eight participants (24 men) with a mean (SD) age of 27.3 yrs. (10.3 yrs., range 18–53 yrs.) were involved in the study. The majority were undergraduate students. Of these, 12 (5 men) reported that they had at least one OBE in their lifetime (further details of participants' OBEs can be found below and in Tables 1 and 2).

2.2. Participant selection

The study was announced by public advertisement posted at local places in and around the University of Bristol as well as after lectures. In the advertisement, we indicated that we were searching for volunteers with previous OBEs. In addition, we controlled for the potential confound that differences between OBE-individuals and nOBE-individuals might be mediated by participants' schizotypal experiences. McCreary and Claridge (1995, 1996, 2002) reported that OBE-individuals as compared to nOBE-individuals reveal more positive schizotypal features (experiences reminiscent of positive symptoms in schizophrenia). Also, positive schizotypy has been reported to impair performance in the present OBT-task (Arzy et al., 2007; Mohr et al., 2006). Thus, we additionally indicated that we are interested in volunteers who strongly believe or disbelieve in extrasensory perception such as spiritual communication, sixth sense and paranormal phenomena.

Prior to study inclusion, interested candidates received further standardized written study information, and were asked to fill in self-report questionnaires (see below). OBE-individuals were further interviewed to verify that they had classical OBEs where the individual felt himself or herself to be in an elevated spatial position, and to see the own body and the world from this elevated perspective (see also Mohr and Blanke, 2005). As indicated by self-report of included candidates, the OBEs were not experienced under the influence of drugs, alcohol, or as the result of accident or trauma. Furthermore, we excluded individuals, who had a previous psychiatric, neurological, or drug history, as well as learning disabilities. Casual consumption of cannabis was not considered an abuse, provided that the time since last consumption was more than two months (and unrelated to OBEs, Overney et al., 2009, this issue). Moreover, for nOBE-individuals, we only tested right-handed participants (see Kita et al., 2007 for cut-off scores) according to a standardized handedness questionnaire (Oldfield, 1971). Based on the rarity of OBEs in the general population (Blackmore, 1982), every OBE-individual was invited to participate [two participants (one man) were non-right-handed].

Motivated by peer review, we contacted all OBE-individuals again to obtain more detailed descriptions about their OBEs. All of them responded by email to a standardized questionnaire. One participant had been excluded for analysis (see under Section 2.6), and was not contacted again. The questionnaire asked (see Tables 1 and 2 for individual answers) 1) for a brief description of what happened when they have an OBE (see Table 1), 2) approximately how many OBEs they had in their lifetime (Num, Table 2), 3) how old they were when they started (First OBE, Table 2), 4) approximately how often OBEs occur now (Freq, Table 2), 5) how long the OBEs lasted (Dur, Table 2), 6) in which physical position they were when OBEs happened, i.e., whether they were led down, sat down, walking around, or a combination (Body Pos, Table 2), 7) whether they have been alert, relaxed or sleepy when OBEs happened, and whether, if they were sleepy, they occurred when falling asleep or when waking up (Alert, Table 2), 8) whether they felt comfortable and happy about their OBEs or whether they left them feeling anxious (Mood, Table 2), 9) how far away they were from their physical body during an OBE, and whether they were above/to the left/to the right of the physical body, or whether this varies (View Pos, Table 2), 10) which body parts of their physical body they were looking at, i.e., face, limbs, torso etc. (See Body, Table 2), 11) how they recognized their physical body as being themselves when they are disembodied, and whether they look as they normally would when they look in the mirror, or whether they looked in some way different (Recog, Table 2),

Table 1 – Brief descriptions of individuals' OBEs (P = participant). In brackets, the sensual experiences during OBEs are provided.

Ps	Description (sensual experiences)
P1	Sensation of being ‘‘elsewhere’’, but physically in same place (feeling weightless)
P2	Not in control of movements outside my body. Feeling cold & loud silence in ears (phantom feeling of physical self, unable to move/interact)
P3	Not being attached to body. Complete stillness of mind. Sometimes seeing images with the feeling they are related to particular person (when entering state of OBE, all sensual feelings fade away)
P4	View myself always from above, e.g., while walking down street (feeling of disembodiment)
P5	Between sleep & wake see self as if someone else, detached from body & looking at self (weightless, temperature irrelevant, unable to physically interact, but everything very very abnormally vivid and bright)
P6	Wake up, realize that I am looking down on myself in bed (weightless, unable to interact)
P7	Playing pool (sober), standing away from myself watching me playing (disembodied self can move and think, but only passively observe environment)
P8	Feels like I see self from another view (outside of my body). See myself as any general person rather than an individuals (as in me) (no particular sensual experiences)
P9	Floated out of my body through back. Looking down on myself lying down in bed (floating in air, not having obvious limbs, OBEs too short to interact with myself or environment)
P10	Detached from physical body, lack of energy to control mental spirits (feel hot and dizzy)
P11	While sleeping, wake up lying in bed, and then realize that I am ‘‘out-of-body’’. See things normally, albeit pitch dark (weightless, temperature irrelevant, sense of touch and pain, moving around as ‘‘sleep-walking’’, experience of illusions)

12) whether they have a sense of weight, temperature, ability to move/physically interact with the environment when they have a sense of disembodiment (sensual experiences, Table 1), and finally 13) whether they ever had the feeling of there being a presence in the room with them knowing that they are quite alone (Presence, Table 2).

The descriptions show several consistencies across individuals. All OBEs here were of visual nature (please note that

Table 2 – Descriptions and phenomenology of individuals' OBEs (descriptions of the different labels in the first column can be found in Section 2 under Section 2.2).

	P1	P2	P3	P4	P5	P6
Sex	Male	Female	Male	Male	Female	Female
Age	20 yrs.	20 yrs.	19 yrs.	41 yrs.	21 yrs.	21 yrs.
Num	6–7	2	4-5	110	4	4
First OBE	11 yrs.	12 yrs.	16 yrs.	16 yrs.	4 yrs.	19 yrs.
Freq	1 period per yr.	2 only	Last 24 months ago	2 per yr.	Rarely	2 per yr.
Dur	Many for several days	5 min	30 min	2 min	Few min	5 min
Body Pos	Sitting	Lying	Lying/sitting	Walking	Lying	Lying
Alert	Sleepy	Sleepy/relaxed	Sleepy (but alert mind)	Alert	Sleepy > waking	Sleepy
Mood	Comfort	Bit anxious	Comfort	No change	2 peaceful/2 shaken	Comfort
View Pos	Above	2–4 feet right	Above	Above, 2 m	Above, close	2 m above
See Body	Face	Face, arm	Not sure	Top of head	WB, face	WB, face, limbs
Recog	LN	IJK	Not sure	LN[a]	LN	LN
Pres	Rarely	Rarely	Yes	No	No	Often

	P7	P8	P9	P10	P11
Sex	Female	Female	Male	Female	Male
Age	23 yrs.	19 yrs.	21 yrs.	19 yrs.	19 yrs.
Num	1	3	3	4–5	20
First OBE	22 yrs.	15 yrs.	14 yrs.	8 yrs.	Always
Freq	Once only	Once in 2 yrs.	Not for while	Last 24 months ago	Every few months
Dur	Few min	2 min	Few min	Few min	20–45 min
Body Pos	Walking	Sitting/standing	Lying	Lying	Lying
Alert	Alert/relaxed	Relaxed	Between wake-sleep	Falling asleep	Falling asleep, waking up
Mood	Anxious	Strange/unnerved	Relaxed/content	Nothing	Interesting
View body	1 m right	Opposite, 1 m right	1 m back, above	Above	Above, right
See body	Face, torso	Face, shoulders	Head, torso	Can't remember	Once upper body
Recog	SF	–	LN	IJK	LN
Pres	No	No	No	No	Rarely

P = Participant, Comfort = comfortable, WB = whole body, LN = look normal, IJK = I just know, SF = Sense of familiarity.
a But I wear more often a white polo shirt than not.

seeing oneself was one major criterion (see Mohr and Blanke, 2005)), some are linked to sleep and sleep paralysis (Cheyne and Girard, 2009, this issue; Girard and Cheyne, 2004), occur mainly in a relaxed state (lying or sitting) (Blanke and Mohr, 2005; Cheyne, 2002), are perceived more frequently in the upper right than left visual field (Brugger et al., 1996; see also Girard and Cheyne, 2004; Girard et al., 2007) with about 1–2 m distance between the physical body and the experienced location of the self (e.g., Blanke and Mohr, 2005; Bradford, 2005; Girard et al., 2007), are of short duration (Blanke and Mohr, 2005), and are sometimes accompanied by a feeling of weightlessness/vestibular sensations (Blanke and Mohr, 2005; Cheyne and Girard, 2009, this issue).

2.3. *Schizotypy questionnaires*

In order to select a control population (nOBE-individuals) with a large range of schizotypy scores, we randomly intermixed 65 items from two true–false self-report positive schizotypy questionnaires.

Magical ideation (MI) scale: This is a validated 30-item positive schizotypy questionnaire (Eckblad and Chapman, 1983) that includes items such as ''I sometimes have a feeling of gaining or losing energy when people look at me or touch me,'' (keyed true) or ''Some people can make me aware of them just by thinking about me'' (keyed true). Scores on the MI scale range from 0 to 30, with higher scores indicating more pronounced magical thinking. The scale is published in full in Eckblad and Chapman (1983), and normative data can be found in Garety and Wessely (1994).

Perceptual Aberration (PA) scale: This is a 35-item positive schizotypy questionnaire (Chapman et al., 1978) that includes items such as ''Occasionally I have felt as though my body did not exist'' (keyed true) and ''I have never felt that my arms or legs have momentarily grown in size'' (keyed false). Additional literature concerning reliable and valid use of the PA scale in the study of schizotypy can be found elsewhere (Chapman et al., 1994; Lenzenweger et al., 1994; Tallent and Gooding, 1999). Higher scores indicate more PA.

2.4. *Mental imagery task*

Body stimuli: Drawings are modified versions used in previous mental own body transformation tasks (Arzy et al., 2007; Arzy et al., 2006; Blanke et al., 2005; Mohr et al., 2006; Ratcliff, 1979; Zacks et al., 1999). The schematic figures were either facing toward or away from the volunteer (Fig. 1). Front- and back-facing figures had the same outline and differed in the rendering of the clothing of the figure and the presence of a face (front-facing; Fig. 1) or the back of a head (back-facing; Fig. 1). The hands of the figures were marked such that one hand appeared as wearing a grey glove with a black ring at the wrist. This indication of side could appear on the right or on the left hand. To assess task switching, the body figures were either surrounded by an oval shape or by a rectangle resulting in eight variations of the stimuli (Fig. 1). These two different frames were used to indicate two different task conditions, as will be outlined in the subsequent paragraph.

2.5. *Procedure*

Participants were set centrally to the computer screen with an eye–screen distance of 57 cm. The keyboard was positioned so that the response keys were comfortably accessible to the responding hand and central to the body midline.

Stimuli were presented in the centre of the computer screen. The figures appeared 9.5 cm $\times$ 6 cm on the screen and the whole image appeared 11.5 cm $\times$ 8 cm on the screen. Each presentation of one of the eight stimuli was preceded by a central fixation cross presented for 800 msec. Where the oval shape surrounded the figure, participants had to make left–right judgments about the indicated human hand of the figure imagining that the human figure was a reflection of their body in a mirror (Mirror-task). If the rectangular shape surrounded the figure, participants had to make left–right judgments about the indicated human hand of the figure after having mentally imagined being in the position of this figure (OBT-task). In both instances, participants had to decide whether the figure's gloved hand would be their own right or left hand. Key 1 on the numeric keypad was used to indicate a ''left hand'' response and key 2 for a ''right hand'' response. All participants responded using the middle and index fingers of their dominant hand, this being the right hand in all but 2 OBE cases. The stimulus remained on the screen until a response was given making the trials self-paced. In line with previous switching tasks, to counteract poor motivation and encourage correct responses (Kleinsorge, 2004; Li, 2004; Miyake et al., 2000), feedback was provided after each trial by presenting centrally on the screen the word ''Great'' in red typeface for a correct response and ''Too bad'' in blue for an incorrect response for 800 ms. It was emphasized to participants that while it was important to respond as swiftly as possible, participants should primarily focus on accuracy and always perform the mental body imagery task before responding.

In order to obtain a measure of switching performance, the sequence was pseudorandomized, i.e., trials of the same instruction were repeated (RepT) between 2 and 6 times before the alternative instruction was presented (SwT). There were a total of 400 trials presented in 2 blocks of 200 trials. Within these 400 trials there were a total of 100 SwT, 50 in each of the two blocks. The number of SwT used here is in excess of those used in comparable switching tasks (e.g., 90 switches in Hester and Garavan, 2005; 48 and 60 switches in Miyake et al., 2000). The RepT and SwT were pseudorandom between blocks, i.e., the order in block 1 was reversed for block 2. Order of block presentation was counterbalanced between participants.

The experimental blocks were preceded by a practice block of 20 trials at the end of which a message was displayed informing participants of the accuracy percentage attained. If the accuracy score was below 60%, participants were required to repeat the practice block before the experimental trial began. Between experimental blocks, participants were able to rest for as long as they needed. The experimental blocks took approximately 10 min each.

2.6. *Data analysis*

One OBE participant (female) was excluded from further analysis. This participant had exceedingly high mean reaction

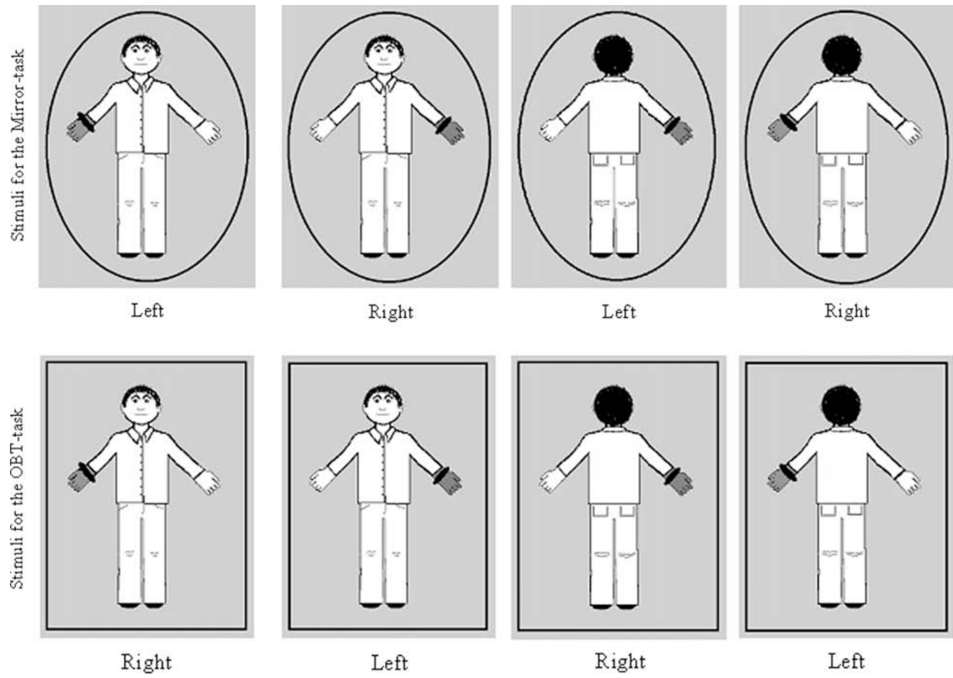

Fig. 1 – Stimuli used in the switching task. In the upper row, the oval shape indicated that participants had to imagine that the figure was their own reflection in a mirror (Mirror-task), while in the lower row, the rectangular shape indicated that participants had to imagine taking the position of the depicted figure (OBT-task). Right–left decisions had to be made with respect to the own body. Correct responses are indicated under each picture.

times (RTs) for RepT (3514.2) and SwT (4807.4) as compared to those of the remaining sample (RepT: 1242.5 ± 285.6; SwT: 1477.43 ± 354.82). The following analyses are thus based on a sample of 47 participants. Five of these participants performed the practice block twice (three nOBE-individuals). Two participants (P4, P7, Table 2) reported OBEs during walking, and might thus be considered atypical (see Tables 1 and 2). Inspecting their mean RTs and mean percent correct responses, they did not differ from the remaining OBE-individuals, but rather led right in the middle of the range of scores of the remaining OBE-individuals.

From this sample, we calculated mean RTs for correct responses and mean percent correct responses for RepT and SwT in the back- and front-facing body positions for the Mirror-task and OBT-task separately. According to previous studies (Kiesel et al., 2007; Miyake et al., 2000), individual data points that were more than 3SD above the participants' mean were removed for RepT and SwT separately.

In order to compare RepT and SwT performance between groups, and to account for the possibility that the dependent variables (mean RT, percent accuracy) were differently affected for the different task conditions, we performed repeated measures ANCOVAs with task condition (RepT, SwT), task instruction (Mirror-task, OBT-task), and body position (front-facing, back-facing) as repeated measures, and group (OBE, nOBE) as between-subject-measures. In order to control that significant findings with respect to group were not mediated by participants' positive schizotypy, (Arzy et al., 2007; McCreery and Claridge, 2002; Mohr et al., 2006), we included the summed MI and PA scores (PerMag scores) as a covariate. Thus, significant main effects and interactions regarding the between-subject factor group are not the result of varying or mediating degrees of positive schizotypy. Post-hoc comparisons correcting for multiple comparisons were performed with Newman–Keuls tests. All *p*-values are two-tailed, and the significance level was set to alpha = .05.

3. Results

3.1. Participants

Separate unrelated t-tests showed that OBE-individuals did not differ from nOBE-individuals in MI scores and PA scores, but that OBE-individuals tended to be younger than nOBE-individuals (Table 3). In line with previous reports (e.g., Chapman and Chapman, 1987; Chapman et al., 1994), MI and PA scores were highly correlated ($r = .72$, $p < .0001$), and were summed to obtain PerMag scores.

Table 3 – Unpaired *t*-tests (*df* = 45) for age and schizotypy scores between OBE-individuals and nOBE-individuals.

	nOBE	OBE	t	p
Age (in yrs.)	28.3 ± 10.4	22.1 ± 6.4	1.88	.07
MI	10.4 ± 8.7	11.8 ± 6.0	−.52	.61
PA	7.6 ± 8.1	11.7 ± 7.8	−1.49	.14

MI: magical ideation scores, PA: perceptual aberration scores.

3.2. Task performance in OBE and nOBE-individuals

The repeated measures ANCOVA on mean RT with task condition (RepT, SwT), body position (back-facing, front-facing), and task instruction (mirror-task, OBT-task) as repeated measures, group (OBE, nOBE) as between-subject-measure, and PerMag scores as covariate showed that response latencies were faster for RepT (1242.5 ± 285.6 ms) than SwT [1477.4 ± 354.8, $F(1,44) = 44.80$, $p < .0001$], for back-facing (1332.5 ± 311.8 ms) than front-facing (1386.0 ± 322.1 ms) figures [$F(1,44) = 10.27$, $p = .003$], and in the OBT-task (1289.8 ± 284.3) than Mirror-task [1428.7 ± 365.9, $F(1,44) = 11.17$, $p = .002$]. The significant interaction between task instruction and body position [$F(1,44) = 29.87$, $p < .0001$] resulted from faster response latencies in the front-facing (1375.4 ± 346.8 ms) than back-facing (1482.0 ± 387.0) body position in the Mirror-task ($p = .002$) and in the back-facing (1183.0 ± 277.8 ms) than front-facing (1396.6 ± 325.3 ms) body position in the OBT-task ($p = .0001$). Moreover, reaction times for back-facing body positions were faster in the OBT-task than Mirror-task ($p = .0002$) and equally fast for front-facing body positions in both task instructions ($p = .46$). The remaining comparisons were not significant (all F-values < 3.82).

The same ANCOVA on percent accuracy showed that more correct responses were made for RepT (93.7 ± 4.5) than SwT [88.9 ± 9.8%, $F(1,44) = 14.54$, $p = .0004$], and in the OBT-task (92.3 ± 7.0) than Mirror-task [90.2 ± 7.7 ms, $F(1,44) = 4.53$, $p = .04$]. The significant interaction between task condition and group [$F(1,44) = 7.84$, $p = .008$] resulted from OBE-individuals performing worse in SwT (83.2 ± 14.4) than RepT (92.5 ± 5.9 ms, $p = .0001$), while the same comparison for nOBE-individuals just failed significance level (SwT: 90.6 ± 7.3; RepT: 94.0 ± 4.0 ms, $p = .055$). Moreover, groups did not differ for RepT ($p = .66$), but for SwT, OBE-individuals performed worse than nOBE-individuals ($p = .03$). The last significant finding (all other F-values < 3.55) was the four-way interaction [$F(1,44) = 4.93$, $p = .03$] indicating that the group difference in SwT and RepT might also depend on body position and task instruction. Post-hoc comparisons (see below) indicate that it is particularly impairing for OBE participants to perform SwT when presented with the commonly less cognitively demanding body positions (front-facing body position in the Mirror-task, back-facing body position in the OBT-task, Fig. 2B). To demonstrate this observation in more detail, none of the post-hoc comparisons were significant 1) between the different percent accuracy measures when only nOBE-individuals were considered (all p-values $> .33$), and 2) for the different percent accuracy measures when compared between nOBE and OBE participants (all p-values $> .44$). When percent accuracy measures were compared for OBE participants only, three major clusters of findings were significant: 1) for back-facing body positions in the OBT-task, OBE-individuals performed worse in SwT than RepT ($p = .0002$) and for front-facing body positions in the Mirror-task, OBE-individuals also performed worse in SwT than RepT ($p = .0002$; Fig. 2A and 2B); 2) for SwT in the Mirror-task, participants performed worse for front-facing than back-facing body positions ($p = .004$), and for SwT in the OBT-task, participants performed worse for back-facing than front-facing body positions ($p = .02$, Fig. 2B); and 3) for SwT of back-facing body positions, participants performed worse in the OBT-task than Mirror-task ($p = .03$), and for SwT of front-facing body positions, participants performed worse in the Mirror-task than OBT-task ($p = .001$; all remaining p-values $> .15$).

4. Discussion

Self representation has been shown to depend on the PFC, TPJ, and their connectivity (e.g., Apperly et al., 2004; Farrer et al., 2004; Fletcher et al., 1995; Gallagher et al., 2000; Saxe and Wexler, 2005; Vollm et al., 2006). Accordingly, we suggested that OBEs might not only be mediated by the TPJ as suggested recently (Blanke and Mohr, 2005; Blanke et al., 2005), but also depend on frontal lobe functioning and processing (Devinsky et al., 1989). To test this hypothesis with neuropsychological behavioral means, we assessed switching performance between two mental own body imagery tasks (Arzy et al., 2006) with the OBT-task being sensitive to both OBEs and TPJ function (Blanke et al., 2005). Switching performance between the OBT-task and the Mirror-task was considered to depend on an intact fronto-parietal network (Chafee and Goldman-Rakic, 1998; Dove et al., 2000; Ruge et al., 2005) including here the PFC and TPJ. If this network is more compromised in OBE-individuals as compared to nOBE-individuals, we predicted that OBE-individuals should yield higher switch costs than nOBE-individuals.

Switching continuously between two tasks, OBE-individuals and nOBE-individuals performed egocentric perspective transformations by making left-right judgments of hands of depicted human figures (Zacks and Michelon, 2005). One instruction (OBT-task) asked participants to imagine that they are in the position of depicted human figures (Arzy et al., 2006; Blanke et al., 2005; Mohr et al., 2006), while the other task instruction (Mirror-task) asked participants to imagine that depicted human figures were a reflection of their bodies in a mirror (Arzy et al., 2006). Accordingly, we showed the same figures but only alternated the cognitive demand with respect to the egocentric bodily perspective that was taken mentally by the participants. The overall findings replicated previous observations that participants were faster and more accurate for front-facing body positions as compared to back-facing body positions in the Mirror-task (Arzy et al., 2006) and for back-facing body positions as compared to front-facing body positions in the OBT-task (Arzy et al., 2007; Arzy et al., 2006; Blanke et al., 2005; Mohr et al., 2006; Zacks et al., 1999). These overall behavioural findings are in agreement with previous reports regarding mental rotation of objects (Shepard and Metzler, 1971; Wohlschläger and Wohlschläger, 1998), and body parts (Bonda et al., 1995; Cooper and Shepard, 1975; Parsons, 1994; Petit et al., 2003; Seurinck et al., 2004): reaction times are longer when the position of a stimulus (the own current body position in the present case) does not match that of the target stimulus (front-facing body positions in the OBT-task and back-facing body positions in the Mirror-task). We also replicated the finding that performance for the OBT-task was superior to the one for the Mirror-task (faster responding,

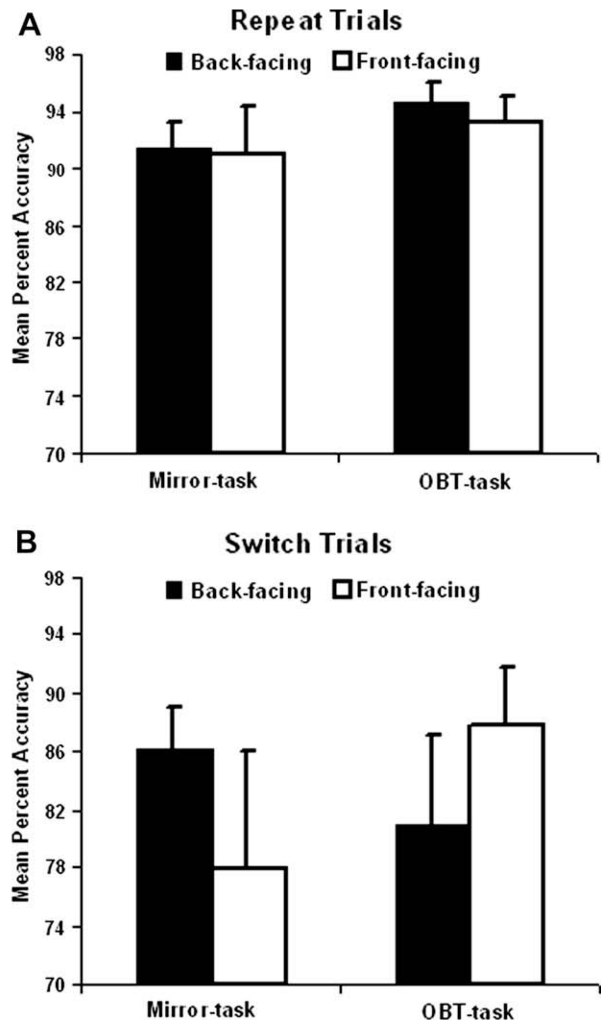

Fig. 2 – Mean percent accuracy for OBE participants in the Mirror-task and OBT-task for back-facing and front-facing body positions for Repeat Trials (A) and Switch Trials (B). Vertical bars denote +1SE.

higher accuracy) (Arzy et al., 2006), indicating that mental imagery employing disembodied self-location and perspective (potentially relating to an extrinsic egocentric coordinate system) is easier to perform than mental imagery employing embodied self-location and perspective (potentially relating to an intrinsic egocentric coordinate system (see e.g., Buxbaum et al., 2000; Shenton et al., 2004)). These overall findings would also indicate that behavioural differences are not altered, at least in the present experimental condition, by whether participants performed SwT or RepT [see Creem-Regehr et al. (2007) for a related behavioural finding when using a block-design or an intermixed-design when assessing two egocentric transformation tasks].

Of crucial importance to the present study is the finding that OBE-individuals did not differ from nOBE-individuals in mean RTs but showed inferior performance to nOBE-individuals with respect to their correctness in switching between the two task instructions, in particular when switching required to respond to the commonly easier body position of each task (front-facing body position in the Mirror-task, back-facing body position in the OBT-task). By controlling for participants' PerMag scores, we could exclude the possibility that this group difference was mediated by individuals' positive schizotypy (Arzy et al., 2007; McCreery and Claridge, 1995, 1996, 2002; Mohr et al., 2006).

Based on the previous literature on the brain correlates of switching performance, the present findings would indicate that fronto-parietal integration might be compromised in OBE-individuals as compared to nOBE-individuals selected from the general population. Previous studies not only reported that effective switching is dependent on the PFC (Kumada and Humphreys, 2006; Mansouri et al., 2006; Passingham et al., 2000), but also that switching performance depends on the dynamic interplay between the PFC and the TPJ and the parietal lobe in general (Chafee and Goldman-Rakic, 1998; Dove et al., 2000; Ruge et al., 2005). Some authors suggested that the flow of information is from the frontal to the parietal lobe with the former relevant to response selection and the latter in stimulus analysis (Ruge et al., 2005). Consequently, we here suggest that OBEs do not only relate to a disintegration of multisensory integration at the TPJ (Blanke et al., 2004; Blanke et al., 2005) but also that the PFC is likely to contribute to this impaired self-processing.

Of special interest is the finding that impaired performance for SwT in OBE-individuals as compared to nOBE-individuals were restricted to front-facing body positions in the Mirror-task and back-facing body positions in the OBT-task, i.e., task conditions commonly facilitated, because they directly match the own current body position (Overney et al., 2009, this issue). On the one hand, the observation that impaired switching is restricted to some but not all body positions seems reassuring: It would exclude, at least to some extent, the obvious possibility that switching in OBE-individuals might be hampered for any switching task (e.g., tasks using objects instead of body stimuli). Only future studies will be able to firmly exclude the possibility that OBE-individuals also show increased switch costs for some but not all object orientations. On the other hand, the present findings are inconsistent with what one could probably expect: impaired switching should rather be observed for SwT of the OBT-task than of the Mirror-task, and potentially also more strongly for the body position mimicking most strongly an OBE (front-facing body positions). Support for this claim would come from previous findings that OBEs relate to TPJ activation when performing mental own body imagery in the OBT-task (Blanke et al., 2005). Since a less dominant TPJ activation was observed for the Mirror-task as compared to the OBT-task (Arzy et al., 2006), one might suggest that the Mirror-task as compared to the OBT-task would be less sensitive to target brain processes related to OBEs. The present study would, however, indicate that at least the sudden confrontation with front-facing figures under the Mirror-task instruction capture some cognitive processes related to OBEs. Thus, individuals with prior OBEs appear to have a general problem when being suddenly instructed to imagine being in a body position and perspective that matches the actual own body position, but only when just having performed egocentric perspective taking within a different coordinate system. Since the Mirror-task is yet little explored [we are only aware of the study by Arzy et al. (2006)], we can only conjecture that the present findings might reflect a more general impairment in spontaneous self-location in OBE-individuals. This impairment might be similar to the self-disturbances reported from patients with passivity symptoms (Farrer et al., 2004; see also Spence et al., 1997). Farrer et al. (2004) showed an aberrant activation of the right angular gyrus when making agency decisions (self, distorted, other) on hands moving a joystick that were perfectly in concordance with the patients' own hand movements. Relating body stimuli (Peled et al., 2003), movement (Farrer et al., 2004; Lindner et al., 2005; Spence et al., 1997), and self-face recognition (but see Irani et al., 2006; Lee et al., 2007) fast and efficiently to oneself seems one cardinal impairment when individuals suffer from pathological forms of self-distortions such as in schizophrenia, which might help to explain the current findings. If this explanation holds true, and the TPJ and its modulation by the PFC would be crucial to OBEs, we would predict that future studies would observe that the two brain areas and their connectivity should relate to the switching impairments described in the present study for stimuli that are in concordance with the own current body position.

In conclusion, the present study tested participants' switching performance between two mental own body imagery tasks using the same visual stimuli and showed that switch costs were higher in OBE-individuals as compared to nOBE-individuals, in particular for the stimuli that matched the participants' actual body position (front-facing body positions in the Mirror-task, back-facing body positions in the OBT-task). This observation suggests that OBEs might be mediated by a functional disconnection of information between the PFC and the TPJ. While previous studies targeting the cerebral underpinnings of OBEs pointed to the role of the TPJ (Blanke et al., 2004; Blanke and Mohr, 2005; Brandt et al., 2005), the present findings extend these observations to the PFC and their anatomical connections. The understanding of the cognition and the brain correlates of disturbance in self representation such as experienced during OBEs and related experiences is yet in its infancy. Recently, neuropsychological studies increase in number using empirical paradigms that are valuable in the understanding of OBEs, whether this refers to clinical (Blanke et al., 2005) or healthy (Arzy et al., 2007; Arzy et al., 2006; Blanke et al., 2005; Mohr et al., 2006) populations. The conjecture we feel safe to formulate is that mental own body imagery appears increasingly valuable in the investigation of disturbed self representation (present study; Arzy et al., 2007; Blanke et al., 2005; Mohr et al., 2006), that OBEs (present study; Blanke et al., 2005) and schizotypal thought (Arzy et al., 2007; Mohr et al., 2006) relate to this cognitive ability.

Finally, we would like to note that we are currently unable to exclude the possibility that other mediating variables might explain the present group difference in SwT. Without being complete, we here list personality variables, physiological measures, and cognitive processes that have previously been related to OBEs: individuals' somatoform (Murray and Fox, 2005a, 2005b) but not general dissociative (Arzy et al., 2007) tendencies, body dissatisfaction (Murray and Fox, 2005b), dissociative alterations in one's body image during a mirror-gazing task (Terhune, 2006), arousal (Nelson et al., 2007), the separation of participants who either experienced their OBEs in a sleep-related or sleep-unrelated state (Cheyne and Girard, 2009, this issue), weak synesthetic experiences (Terhune, 2009, this issue), and cannabis use (Overney et al., 2009, this issue). Also, if the present findings point to a specific impairment of OBE-individuals to quickly imagine a perspective that matches the own actual body position (when having performed a different perspective taking task before), TPJ activation might also be engaged during unexpected confrontations with the own face. Certainly, it remains to be elucidated why OBE-individuals were not generally impaired for front-facing body positions in the Mirror-task and back-facing body positions in the OBT-task as well (RepT) (Overney et al., 2009, this issue), but only when switching to these trials. If it is the sudden change to match a body stimulus perfectly concordant with the own current body position, then, the here observed increased switch costs in OBE-individuals may be reduced in a cued task switching paradigm with increasing cue–target-intervals (Rogers and Monsell, 1995). This suggestion would be supported by a recent study showing that disturbed self presentation in schizophrenia might relate to early processing stages of stimulus characteristics (Posada et al., 2007). Finally, it remains to be elucidated why the feeling of self agency is not compromised in OBE but in schizophrenia (Frith, 2005) as well as in independent delusional misidentifications (Feinberg and Keenan, 2005). Despite these open questions, and given the hypothesis-based predictions generated from previous studies (Blanke and Mohr, 2005; Mohr and Blanke, 2005), we conjecture that OBEs are mediated by a disintegration of information from the PFC, and that the testing of individuals with previous OBEs, albeit not experiencing one at the time of testing, might be valuable to gain insight into brain mechanisms related to intact as well as dysfunctional processing related to self representation.

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