Clinical commentary

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Anatomical electroclinical correlations during an SEEG-recorded seizure with autoscopic hallucination

Davide Fonti [1,2], Stanislas Lagarde [2], Julia Scholly [2], Anne Lépine [3], Didier Scavarada [4], Monica Puligheddu [1], Aileen McGonigal [2], Fabrice Bartolomei [2]

[1] Department of Medical Sciences and Public Health, Neurology Section - University of Cagliari, Italy
[2] Aix Marseille Univ, APHM, INSERM, INS, Inst Neurosci Syst, Timone Hospital, Epileptology Department, Marseille, France
[3] APHM, Timone Hospital, Pediatric Neurology Department, Marseille, France
[4] Aix Marseille Univ, APHM, INSERM, INS, Inst Neurosci Syst, Timone Hospital, Pediatric Neurosurgery Department, Marseille, France

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ABSTRACT – Autoscopic phenomena (AP) are characterized by seeing an image of oneself in extra-personal space. These phenomena are rare and the anatomy of brain regions producing these phenomena is not well defined. We report anatomical electroclinical correlations during a stereoelectroencephalography-recorded seizure with autoscopic hallucination (a form of AP in which the double of oneself is seen from an internal point of view). Seizure onset zone was quantified using the epileptogenicity index method (EI). Maximal EI values were obtained in the left lateral parietal cortex (supramarginal gyrus) and high values were also found in the left posterior-superior insular cortex, left temporo-occipital junction and contralateral inferior parietal lobule. Our case confirms the involvement of the inferior parietal lobule, temporo-parieto-occipital junction and posterior insula in the genesis of autoscopic hallucination.

Key words: SEEG, autoscopic hallucination, focal seizure

Autoscopic phenomena (AP) are characterized by seeing an image of oneself in extra-personal space. AP are usually classified on the basis of their phenomenological characteristics, into three main types:
– out-of-body experience, in which the hallucination of one's own body is viewed from an extra-personal perspective;
– autoscopic hallucination or "mirror hallucination", in which the double of oneself is seen from an internal point of view;
– and heautoscopy, an intermediary form, in which there is an illusion that the image represents a doubling of oneself due to difficulty in localizing the "self" and the point of view (Blanke and

Correspondence:
Fabrice Bartolomei
Service d'Epileptologie et Rythmologie Cérébrale,
CHU Timone - 264 Rue St Pierre
13005-Marseille, France
<fabrice.bartolomei@ap-hm.fr>

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Mohr, 2005; Anzellotti *et al*., 2011; Heydrich and Blanke, 2013).
These phenomena are rare and have been described in focal and generalized epilepsies, migraine, cerebral infarction, infection, intoxications, tumors, psychiatric disorders and in healthy people (Devinsky *et al*., 1989; Blanke and Mohr, 2005; Anzellotti *et al*., 2011; Heydrich and Blanke, 2013).
The anatomy of cerebral regions producing these phenomena are less well known than the nature of the alteration, which may be visual, proprioceptive and/or vestibular (Anzellotti *et al*., 2011). AP represent an interesting and important way to better understand the brain representation of the "self".
In this study, we report a patient who presented ictal autoscopic hallucination during stereoelectroencephalography (SEEG) recordings performed for presurgical purposes. SEEG signals were quantified using the epileptogenicity index (EI) method in order to precisely map the regions involved and to perform anatomical electroclinical correlations.

Case study

A 14-year-old female patient underwent presurgical evaluation of her drug-resistant epilepsy in our epilepsy unit. She was born from a twin pregnancy and in the prenatal period had undergone *in utero* electrocoagulation for twin-to-twin transfusion syndrome. There was no family history of epilepsy and her development was normal. Her epilepsy started when she was 12 years old. Different antiepileptic drugs were tried but she had never been seizure-free, with weekly focal seizures and one focal to bilateral tonic-clonic seizure every three months. She reported subjective symptoms such as a "vague or strange feeling" in her head. Very rarely, she reported AP during her seizures, in which she had the impression of seeing her face as if in a mirror. Seizures were characterized by behavioural arrest, with or without mild impairment of awareness, left head and trunk deviation, some verbal automatisms, motor deficit of her right hand and sometimes facial contraction and tonic posturing of her right hand. Interictal neurological examination was normal. Neuropsychological work-up showed a deficit in auditory memory and in the treatment of spatial information and calculation. A presurgical work-up was conducted. Interictal surface EEG showed left temporal spikes and polyspikes during sleep, which spread to suprasylvian electrodes. Magnetic resonance imaging (MRI) showed bilateral perisylvian polymicrogyria and 5-fluorodeoxyglucose positron emission tomography (FDG-PET) showed hypometabolism of the left internal temporal region extending to the left temporal-parietal-occipital junction. Functional MRI for language showed probable right dominance that was later confirmed by a Wada test. During video-EEG, seizures were recorded with ictal discharges maximal on C3, P3 and T5 electrodes. A magnetoencephalography (MEG) study showed predominant localisation of interictal spikes in the left peri-lesional area; overall parietal but also in the posterior insula and lateral temporal cortex.
A video-SEEG was carried out in order to better understand the epileptic network and the implication of functional areas. The patient and her parents were informed that her data might be used for research purposes and signed consent was obtained. The decision about anatomical positioning of the electrodes was established on the basis of the available non-invasive data and hypotheses about the localization of the epileptogenic zone. Electrodes (Dixi Medical [France]; 10-18 contacts, length: 2 mm, diameter: 0.8 mm, 1.5 mm apart) were placed using the neuronavigation frameless method (Skoch *et al*., 2017). A postoperative computerized scan (CT) was performed in order to verify the absence of bleeding and the position of each recording lead. Subsequently, CT scan/MRI data fusion was performed in order to accurately identify and locate each contact along the electrode trajectory using specific in-house software (Gardel; available at: http://meg.univ-amu.fr/wiki/GARDEL:presentation) (Medina Villalon *et al*., 2018). Thirteen electrodes were implanted in the left hemisphere and three on the right side (*figure 1*). Signals were recorded on a 128-channel Deltamed TM system. They were sampled at 1,024 Hz and recorded on a hard disk (16 bits/sample) without a digital filter. The only filter present in the acquisition procedure was a hardware analogue high-pass filter (cut-off frequency equal to 0.16 Hz), used to remove very slow variations that sometimes contaminate the baseline. The seizure onset zone was quantified using the EI (Bartolomei *et al*., 2008) with Anywave software (Colombet *et al*., 2015). EI ranks brain structures according to the "tonicity" of the fast discharge (ratio of high frequency content over low frequency) and the delay of involvement at seizure onset. It combines:
– the change in signal energy from lower frequency band (delta, theta, alpha) towards higher frequency band (beta, gamma) at the transition from preictal to ictal activity;
– and the delay of change in a given electrode contact (brain structure) with respect to initial contacts.
It uses normalized values from 0 to 1, with 1 corresponding to the most epileptogenic region. To compute the EI, we used the plugin designed for the open-source AnyWave software (available at: http://meg.univ-amu.fr/wiki/AnyWave). On the basis of the video-SEEG findings, a left parieto-insular cortectomy, including polymicrogyric cortex, was performed after a Wada test confirmed right hemispheric

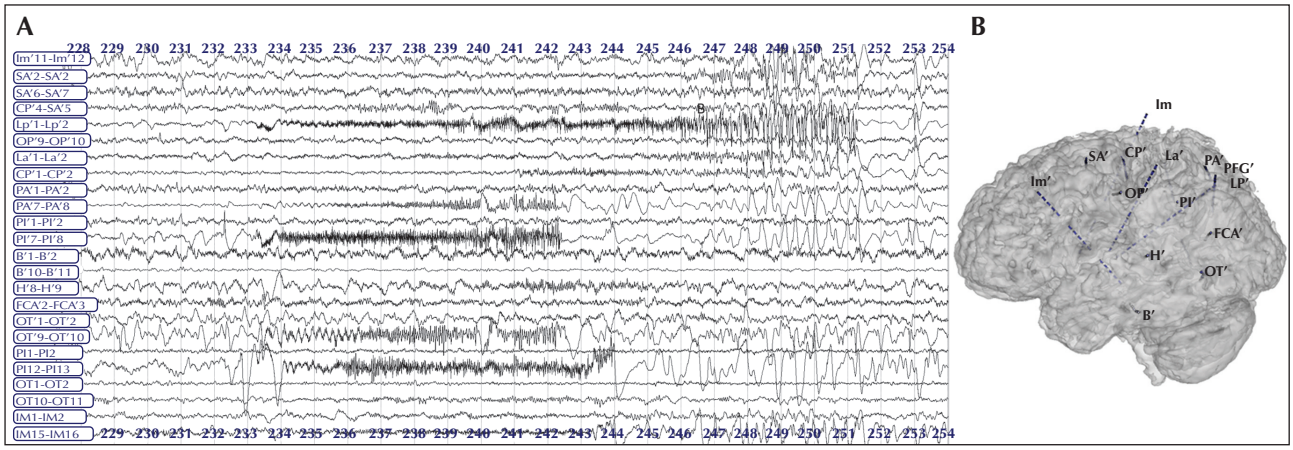

Figure 1. (A) SEEG traces; reduced montage. Electrodes are identified by letters and the recording leads are numbered from 1 to 18; low numbers correspond to the deepest structures. Im' 11-12: left pre-frontal cortex; SA' 1-2: left supplementary motor area; SA' 6-7: left lateral pre-motor cortex; CP' 4-5: left central sulcus; Lp' 1-2: left posterior insula; CP' 1-2 post-central lobule; PA' 1-2: left precuneus; PA' 7-8: left superior parietal lobule; PI' 1-2: posterior cingular gyrus; PI' 7-8 left polymicrogyric cortex in the supramarginal gyrus; B' 1-2: left hippocampal gyrus; B' 10-11: left medium temporal gyrus; H' 8-9: left Heschl gyrus; FCA' 2-3: left cuneus; OT' 1-2: left lingular gyrus; OT' 9-10: left anterior occipital sulcus; PI 1-2: right posterior cingular gyrus; PI 12-13: right polymicrogyric cortex in the inferior parietal lobule; OT 1-2: right lingular gyrus; OT 10-11: right medium temporal gyrus; Im 1-2: right anterior insula; Im 15-16 right post-central gyrus. Electrographically, the seizure started 2.5 s before the first clinical manifestations, with a rapid discharge in the beta-gamma band in the left parietal cortex, at the inferior part of intraparietal sulcus (electrode PI', contacts 7-8) and within the posterior-superior insular cortex (electrode Lp', contacts 1-2). Discharge is seen within the contralateral polymicrogyric cortex (inferior parietal lobule; electrode PI, contacts 12-13) and within the left temporo-occipital junction (electrode OT', contacts 9-10). The seizure was brief, lasting less than 20 seconds. (B) MRI 3D mesh with electrode positions. Im: medium insula; SA: supplementary motor area; CP: paracentral; OP: parietal operculum; La: anterior lesion; PA: superior parietal lobule; PFG: posterior fusiform gyrus; Lp: posterior lesion; PI: inferior parietal lobule; FCA: anterior calcarine sulcus; OT: occipito-temporal; H: Heschl gyrus; B: hippocampal gyrus. The apostrophe denotes left electrodes.

dominance for language. The evolution was marked by a partially regressive right-side hemiparesis and the patient is currently seizure-free (after nine months of follow up). We reviewed electroclinical correlations of the seizure to establish which cerebral areas where involved during ictal autoscopic hallucination.

Results

Several electroclinical seizures were recorded, including one in which the patient reported an autoscopic hallucination. Clinical expression of the seizure started with sudden behavioural arrest and staring; she then warned her mother and presented with left trunk and head deviation and hypotonia of her right hand. She was interviewed at the end of one of the seizures, and she reported a "strange thing", "like I was looking at myself", indicating her face. She described this from an internal point of view, *i.e.*, a characteristic description of autoscopic hallucination. On SEEG recordings, the seizure started 2.5 s before the first clinical signs with a rapid discharge in the beta-gamma band in the left parietal cortex, inferior part of the intraparietal sulcus and within the posterior-superior insular cortex. A fast discharge was seen within the contralateral polymicrogyric cortex (inferior parietal lobule) and within the left temporo-occipital junction (*figure 1*). In the last part of the seizure, delta/ theta rhythmic activity was seen spreading to the fronto-opercular regions, and the anterior insula. Seizures were brief, lasting less than 20 seconds, and EI was maximum in the left lateral parietal cortex, at the posterior and inferior limit of the polymicrogyric cortex, in the supramarginal gyrus (*figure 2*). High EI values were also found in the temporo-parieto-occipital (TPO) cortex and the posterior insula. Electrical stimulations of the different explored regions failed to reproduce this phenomenon.

Discussion

To our knowledge, this is the first video-SEEG description of a spontaneous seizure with an autoscopic hallucination. Ictal spontaneous heautoscopy and out-of-body experience have been described with subdural grids (Blanke, 2004; Heydrich and Blanke, 2013) and other reports describe these phenomena induced by electrical stimulation with SEEG or subdural grids (Blanke *et al.*, 2002; Blanke, 2004; Jonas *et al.*, 2014). These phenomena can be difficult to distinguish from

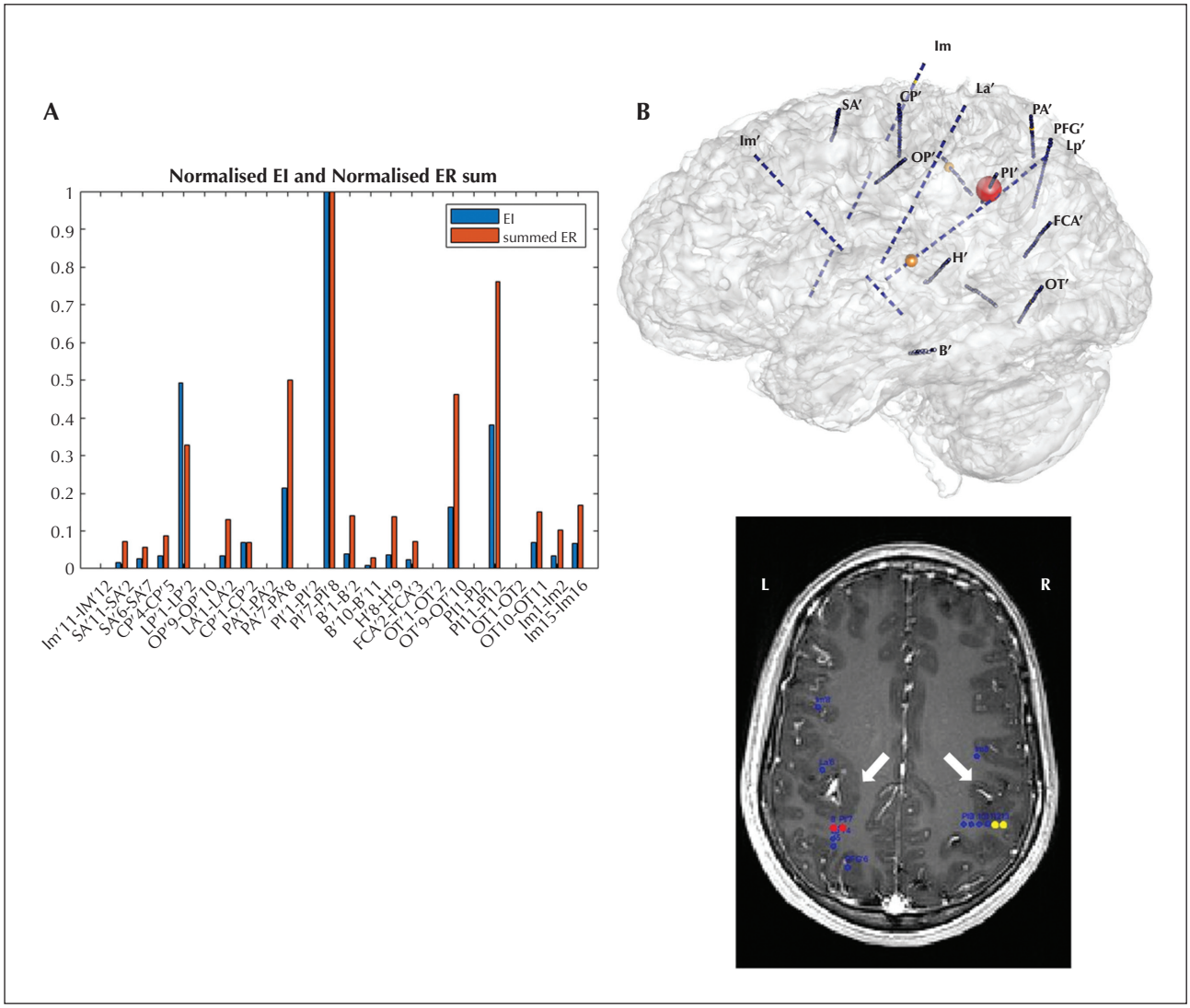

Figure 2. (A) Normalized epileptogenicity index (EI) values. EI ranks brain structures according to the "tonicity" of the fast discharge (energy ratio of high frequency content over low frequency; red bars) and the delay of involvement at seizure onset. The normalized values range from 0 to 1 (blue bars), with 1 corresponding to the most epileptogenic region. To compute the EI, we used the plugin designed for the open-source AnyWave software (available at: http:// meg.univ-amu.fr). The max EI value was observed in the left supramarginal gyrus (PI' 7-8) and high EI values (>0.3) in the left posterior inferior insula (Lp' 1-2) and right supramarginal gyrus (PI 12-13). (B) 3D mesh and axial T1-weighted MRI with electrode positions and representation of EI. Max EI was observed in the left polymicrogyric cortex in the supramarginal gyrus (electrode PI' contacts 7-8, red dot). High EI values were also found in the left posterior-superior insular cortex (electrode Lp', contacts 1-2; yellow dot) and contralateral polymicrogyric cortex (electrode PI, contacts 12-13; yellow dot). The polymicrogyric cortex is indicated by arrows.

dreamy state phenomena (Vignal *et al.*, 2000; Maillard *et al.*, 2004) and this could be the reason why different possible anatomical organizations of seizures producing AP have been proposed (Devinsky *et al.*, 1989; Sveinbjornsdottir and Duncan, 1993; Blanke and Mohr, 2005; Heydrich and Blanke, 2013).

Our case shows that the most involved area in the seizure was the left lateral parietal cortex, at the postero-inferior limit of the polymicrogyric cortex. Seizures involved the supramarginal gyrus together with marked involvement of the ipsilateral posterior superior insula, temporo-occipital junction and contralateral inferior parietal lobule. In the genesis of autoscopic hallucination, involvement of parietal lobe cortex and the TPO junctions has been already described and it has been suggested that this could cause disruption of the integration of the different sensorial inputs (vestibular, somatosensory and visual)

that are necessary to create a central representation of one's own body (Devinsky *et al*., 1989; Blanke and Arzy, 2005; Blanke and Mohr, 2005; Orban *et al*., 2006; Caspers and Zilles, 2018). Blanke and Mohr proposed that the different forms of AP could be related to the involvement of different cerebral areas, in particular, that out-of-body experience and heautoscopy are related to the right and left temporo-parietal junction, respectively, and that autoscopic hallucination is associated with more posterior right temporo-occipital and parieto-occipital junctions (Blanke and Mohr, 2005).

Jonas and colleagues described two cases of self-face hallucination in the left visual field induced by electrical stimulation of the medial and lateral part of the right occipito-parietal sulcus and right-posterior precuneus at the edge of the occipito-parietal sulcus (Jonas *et al*., 2014). Our findings suggest that autoscopic hallucination is strongly linked to the involvement of the inferior parietal cortex while occipital cortex was not involved in our case. Our patient had left hemisphere onset, but this hemisphere was non-dominant, which is therefore consistent with previous reports suggesting origin in the non-dominant hemisphere. However, the lateralization of these phenomena is not well established (Blanke and Mohr, 2005).

In addition to inferior parietal cortex involvement, we observed a clear discharge within the posterior insula. In a previous report, left posterior insular involvement was described in cases with heautoscopy (Heydrich and Blanke, 2013). It was postulated that insular involvement can cause disintegration between somatosensory-visual signals and emotional-interoceptive signals, and interestingly in heautoscopy, there is often an important emotional correlate, which can be, in some cases, negative to such an extent that it is accompanied by suicidal behaviour (Brugger *et al*., 1994; Anzellotti *et al*., 2011). Late frontal opercular involvement with slow activity was also present in our case and probably even not directly related to the autoscopic hallucination. It is important to note that a role of the frontal cortex and its connectivity with parietal lobes in facial processing and hallucinations of faces in AP has already been suggested (Devinsky *et al*., 1989; Vignal *et al*., 2000; Easton *et al*., 2009).

Although there are limitations in this study, in particular, the presence of abnormal congenital polymicrogyric cortex that can alter anatomical and functional correlates, our case confirms the involvement of the inferior parietal lobule, TPO junction and posterior insula in the genesis of autoscopic hallucination. □

Disclosures.
None of the authors have any conflict of interest to declare.

References

Anzellotti F, Onofrj V, Maruotti V, *et al*. Autoscopic phenomena: case report and review of literature. *Behav Brain Funct* 2001; 7: 2.

Bartolomei F, Chauvel P, Wendling F. Epileptogenicity of brain structures in human temporal lobe epilepsy: a quantified study from intracerebral EEG. *Brain* 2008; 131: 1818-30.

Blanke O. Out of body experiences and their neural basis. *BMJ* 2004; 329: 1414-5.

Blanke O, Arzy S. The out-of-body experience: disturbed self-processing at the temporo-parietal junction. *Neuroscientist* 2005; 11: 16-24.

Blanke O, Mohr C. Out-of-body experience heautoscopy and autoscopic hallucination of neurological origin Implications for neurocognitive mechanisms of corporeal awareness and self-consciousness. *Brain Res Brain Res Rev* 2005; 50: 184-99.

Blanke O, Ortigue S, Landis T, Seeck M. Stimulating illusory own-body perceptions. *Nature* 2002; 419: 269-70.

Brugger P, Agosti R, Regard M, Wieser HG, Landis T. Heautoscopy epilepsy and suicide. *J Neurol Neurosurg Psychiatry* 1994; 57: 838-9.

Caspers S, Zilles K. Microarchitecture and connectivity of the parietal lobe. *Handb Clin Neurol* 2018; 151: 53-72.

Colombet B, Woodman M, Badier JM, Benar CG. AnyWave: a cross-platform and modular software for visualizing and processing electrophysiological signals. *J Neurosci Methods* 2015; 242: 118-26.

Devinsky O, Feldmann E, Burrowes K, Bromfield E. Autoscopic phenomena with seizures. *Arch Neurol* 1989; 46: 1080-8.

Easton S, Blanke O, Mohr C. A putative implication for fronto-parietal connectivity in out-of-body experiences. *Cortex* 2009; 45: 216-27.

Heydrich L, Blanke O. Distinct illusory own-body perceptions caused by damage to posterior insula and extrastriate cortex. *Brain* 2013; 136: 790-803.

Jonas J, Maillard L, Frismand S, *et al*. Self-face hallucination evoked by electrical stimulation of the human brain. *Neurology* 2014; 83: 336-8.

Maillard L, Vignal JP, Anxionnat R, Taillandiervespignani L. Semiologic value of ictal autoscopy. *Epilepsia* 2004; 45: 391-4.

Medina Villalon S, Paz R, Roehri N, *et al*. EpiTools: a software suite for presurgical brain mapping in epilepsy: intracerebral EEG. *J Neurosci Methods* 2018; 303: 7-15.

Orban GA, Claeys K, Nelissen K, *et al*. Mapping the parietal cortex of human and non-human primates. *Neuropsychologia* 2006; 44: 2647-67.

Skoch J, Adelson PD, Bhatia S, *et al*. Subdural grid and depth electrode monitoring in pediatric patients. *Epilepsia* 2017; 58(1): 56-65.

Sveinbjornsdottir S, Duncan JS. Parietal and occipital lobe epilepsy: a review. *Epilepsia* 1993; 34: 493-521.

Vignal JP, Chauvel P, Halgren E. Localised face processing by the human prefrontal cortex: stimulation-evoked hallucinations of faces. *Cogn Neuropsychol* 2000; 17: 281-91.

TEST YOURSELF

(1) What are the different forms of autoscopic phenomena?

(2) Which epileptic network is involved in ictal autoscopic hallucination according to the results of the current study?

Note: Reading the manuscript provides an answer to all questions. Correct answers may be accessed on the website, www.epilepticdisorders.com, under the section "The EpiCentre".