Anosognosia for hemiplegia, the apparent unawareness of one’s contralesional motor deficits, is one of the most counter-intuitive symptoms seen in clinical neurology. Patients with anosognosia for hemiplegia typically have right perisylvian lesions and insist that they can move their paralysed limbs; they may produce elaborate excuses and confabulations when confronted with evidence of their paralysis, or show a marked indifference to their disabilities. Patients’ insight into their illness and corresponding behaviour can vary between sessions, but their anosognosic beliefs seem typically entrenched and can be characterized as delusional. For example, patients may claim that they can move even after clear motor failures, including falls and injuries. Moreover, some patients experience the illusion of moving their limbs when attempting to perform an action, and seem unable to realize that their experience is illusory (Fotopoulou et al., 2008).

There has been a long-held fascination among clinicians on the variability of anosognosia for hemiplegia. Accumulating studies in the second half of the 20th century led to the identification of several concomitant sensorimotor and cognitive impairments and the development of corresponding deficit theories. The theoretical focus on anosognosia for hemiplegia changed, however, in the last two decades as bodily self-consciousness became increasingly recognized as a central scientific topic in cognitive neuroscience. In this context, the understanding of anosognosia for hemiplegia has been enriched by at least four developments: (i) theoretical hypotheses, stemming from philosophical or computational approaches on motor and embodied cognition, that view anosognosia for hemiplegia as a specific disorder of motor awareness rather than a secondary consequence of deficits in other domains (e.g. Frith et al., 2000); (ii) improvements in neuroimaging research that allowed the identification of brain lesions selectively associated with anosognosia for hemiplegia (Berti et al., 2005); (iii) well-controlled, psychophysical experiments that supplemented neuropsychological assessments of patients (Jenkinson and Fotopoulou, 2010); and (iv) new diagnostic tests and meta-analysis of diagnostic criteria that allowed a more precise view of the prevalence and clinical variability of anosognosia for hemiplegia (Orfei et al., 2007).

The study by Garbarini et al. (2012) in the present issue (page 1486) exemplifies all four of these developments. On the basis of an innovative lesion mapping study (Berti et al., 2005), this group was one of the first to claim that anosognosia for hemiplegia can be understood as a specific disorder of motor error monitoring. Following their lead, our group investigated for the first time the relation between motor intention and motor unawareness in anosognosia for hemiplegia (Fotopoulou et al., 2008). We were able to confirm the hypothesis that patients’ movement illusions reflect an abnormal dominance of motor intentions over visual sensory information about the actual effects of movement. These studies are consistent with computational models of motor control (Wolpert, 1997) and their predictions about the role of forward and inverse models in ‘normal’ and ‘delusional’ unawareness (Frith et al., 2000). For these theoretical conclusions to hold, however, a behavioural demonstration of the presence of motor intentions in anosognosia for hemiplegia is needed, over and above previous physiological findings (Berti et al., 2007). The study of Garbarini et al. (2012) provides the first such demonstration by taking advantage of a previously established bimanual interference (coupling) effect in healthy individuals; when individuals try simultaneously to perform different actions with their hands (e.g. drawing circles with the left hand while drawing straight lines with the right), the activities of one hand may interfere with those of the other, so that a ‘compromised’ action emerges from one side or the other (e.g. the lines of the right hand may take an oval shape). Three patients with right perisylvian lesions and anosognosia for hemiplegia showed a comparable interference effect in their right hand with a group of healthy participants, even though their left, paralysed hand did not execute any movements. This finding suggests that motor planning is intact in anosognosia for hemiplegia.

Garbarini et al. (2012) also tested two right hemisphere lesioned control groups, hemiplegic patients without anosognosia for hemiplegia and non-hemiplegic patients with motor neglect. Surprisingly, the former control group showed no evidence of an interference effect. This finding could indicate loss of the ability to generate motor plans, but this interpretation is not supported by previous studies (Berti et al., 2007; Fotopoulou et al., 2008). Alternatively, given their awareness, these patients may not have attempted to follow the instructions regarding their paralysed arm. Thus, the innovative addition of the motor neglect group was highly pertinent and it revealed a double dissociation between movement awareness and motor planning. Patients with motor neglect that are, at least clinically, aware of their ability to move...
were found not to plan, nor initiate movements on their affected side, whereas patients with anosognosia for hemiplegia, who are unaware of their paralysis, were shown to continue planning movements. Future studies could further explore the relation of this dissociation with online awareness of movement and non-movement in both groups, by integrating awareness testing in similar experiments.

The study by Garbarini et al. (2012) includes one further revealing condition. None of the groups showed an interference effect on right hand movements, when they were asked to imagine that they were simultaneously performing a different task with their left hand. Previous studies have found behavioural effects of motor imagery in both healthy participants and right hemisphere patients with and without anosognosia for hemiplegia (Jenkinson et al., 2009) and hence the Garbarini et al. (2012) finding may indicate failure to comply with the motor imagery instruction in their particular task. Alternatively, as the authors claim, their null finding may relate to the neurocognitive independence of motor imagery from motor planning, despite previous contrary indications in healthy individuals and in right hemisphere patients, with and without anosognosia for hemiplegia (Hildebrandt and Zieger, 1995). Irrespective of these interpretations, however, the parallel consideration of motor intention and motor imagery highlights an outstanding question; the aforementioned studies have not been able to specify which aspects of anticipatory motor representation are most relevant to motor unawareness.

More generally, although understanding anosognosia for hemiplegia as a specific disorder of motor awareness has undoubtedly been a step in the right direction, current modular sensorimotor theories of anosognosia for hemiplegia seem to leave out more clinical variability than they actually explain. For example, we recently showed that patients with anosognosia for hemiplegia having implicit awareness into their deficits have fewer lesions in premotor and parietal cortex, compared with an anosognic patient without implicit awareness (Fotopoulou et al., 2010). This preliminary finding suggests that, at least in some patients, the sparing of these cortical areas may actually allow motor monitoring and implicit awareness of deficits, but this is not sufficient to generate explicit awareness. Other lesions involving the insula cortex, subcortical limbic and paralimbic regions as well as extensive damage to white matter may be implicated in the explicit, delusional aspects of anosognosia for hemiplegia.

In acknowledging such limitations, Garbarini et al. (2012) and other groups (e.g. Orfei et al., 2007; Cocchini et al., 2010; Vocat et al., 2010) suggest a revival of theories that implicate two or more contributory factors (cf. Levine et al., 1991). However, the clinical variability of anosognosia for hemiplegia, including its less understood dynamic, emotional and delusional features [see Fotopoulou (2010) for review], can be explained by recent computational models in a single and neurobiologically plausible formulation. In cognitive neuropsychiatry, delusions have been traditionally understood as abnormalities in the mechanisms of normal belief formation. The latter, entails a permanent tension between two demands in potential conflict: beliefs should tally with the existing web of beliefs (conservatism); and beliefs should adhere to the deliverance of current perception [observational adequacy: Stone and Young (1997)]. Anosognosic and other delusions can be hypothesized to involve abnormalities in the dynamic balance between these two poles. In the aforementioned computational models that contextualize the Garbarini et al. (2012) study, this antagonism was limited to the domain of action and concerned efferent (predictive) and afferent (feedback) sensorimotor signals. In contrast, in recent ‘predictive coding’ models of brain function, delusions can be linked to a more general antagonism between ‘prior beliefs’ (predictive internal models of the world formed on the basis of previous learning) and ‘prediction errors’ (discrepancies based on ascending interoceptive and exteroceptive signals: Corlett et al., 2009; Fotopoulou, 2012). These models are driven by the (arguably reductionistic) notion that the brain works as a Helmholtzian inference machine that is trying to optimize its own (Bayesian) probabilistic model of the world by actively predicting the causes of its sensory inputs. Perception and action both serve this optimization [reduction of prediction error, surprise or free energy, see Friston (2010)] by changing predictions, or the signals being predicted, respectively.

These models envision a mismatch between expectation and experience in various levels of the neurocognitive hierarchy and in relation to several cognitive and emotional domains. Thus, they can explain the motor illusions of patients similar to those studied by Garbarini et al. (2012) but they can also explain the more general, obstinate adherence of other patients to their premorbid everyday habits (e.g. “Of course, I can walk”). Insula- or limbic-based interoceptive and cortical-based exteroceptive deficits may lead to an inability to update priors based on weak, or absent signals about prediction errors; and dopamine-depleting lesions in fronto-striatal circuits may lead to a more general difficulty in optimizing the precision (uncertainty) of prediction errors (Friston et al., 2012). Moreover, these models could potentially explain the spontaneous (Vocat et al., 2010) or intervention-based (Fotopoulou et al., 2009) changes of unawareness in time, as progressive updating of priors based on accumulating or alternative signals about prediction errors, respectively. More generally, studies in healthy volunteers on how different primary sensorimotor signals are dynamically integrated and re-represented in various levels of the neurocognitive hierarchy as well as post-stroke studies on brain reorganization in relation to such hierarchical functions, may allow a new, more dynamic understanding of the mechanisms of motor and body awareness. Although the precise measurement of such dynamic, large-scale network operations is still in its infancy, recent longitudinal studies (Vocat et al., 2010) in anosognosia for hemiplegia and future anatomical and functional connectivity studies may reveal some of these mechanisms. Thus, on the one ‘hand’, the current, innovative study by Garbarini et al. (2012) on anosognosia for hemiplegia has firmly moved the literature one step further, on the other ‘hand’, it has allowed us a better view of the many more steps that lie ahead.

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Rhombencephalosynapsis: new findings in a larger study

Rhombencephalosynapsis is a developmental midline defect affecting the cerebellar vermis. The absence of the vermis in rhombencephalosynapsis may be compared to the other condition in which the vermis is largely absent. In Joubert syndrome, the cerebellar hemispheres are close to normal in volume; the intervening vermis is small and much shortened, leaving a gap between the cerebellar hemispheres. The absence of the vermis in rhombencephalosynapsis, like Joubert syndrome, may be normal; ataxia was the most frequent physical finding in a case report by M. Lebenthal and D. K. Lebenthal (1989) in 40 foetuses after medical termination of pregnancy.

The debut of the rhombencephalosynapsis story is credited to Obersteiner in 1916 with a detailed case report entitled ‘Ein Kleinhirn ohne Wurm’ (‘A cerebellum without vermis’) describing the autopsy findings in a 31-year old male. The original study is still worth reading for its wealth of detail such as absence of the mesencephalic trigeminal nucleus and misrouting of tracts at the lower mesencephalic level. Over 100 cases have since been published, mostly as case reports or small series. A review lists 58 published cases before 2005 (Barth, 2008). Hydrocephalus due to aqueductal stenosis is often present at birth. Other cerebral malformations typically affecting the midline may be found including aplasia of the septum pellucidum, fusion of the fornices and holoprosencephaly. Morphological studies reported by Pasquier et al. (2009) in 40 foetuses after medical termination of pregnancy showed fusion of colliculi, forking and/or atresia of the aqueduct, fusion of the thalami, callosal agenesis, lobar holoprosencephaly and neural tube defects as associated findings. Attention was drawn to the frequent occurrence of ‘Vertebral anomalies, Anal atresia, Cardiovascular anomalies, Trachea-oesophagus fistula, Renal anomalies, Limb defects’ (VACTERL) as associated findings.

The cognitive outcome in patients with rhombencephalosynapsis may be normal; ataxia was the most frequent physical finding in a case report by M. Lebenthal and D. K. Lebenthal (1989) in 40 foetuses after medical termination of pregnancy.