something X-shaped is before one. The first-order representationalist can explain this difference by appeal to manners of representing, via the 'impure' representational properties (Chalmers 2005) of visually vs tactually representing that something X-shaped is before one. Or consider blurrily seeing an X: first-person reflection arguably reveals the experience to be blurry, but blurriness is also plausibly a manner of representing (Crane forthcoming). The same strategy could perhaps distinguish perceiving from judging that something X-shaped is before one (see *phenomenology). Such manners influence how an experience is for its subject, seem to be qualities of the experience (just as a slow run is an episode with slowness as a quality), and fail to be representational properties; so accepting impure representational properties as phenomenal characters requires accepting non-representational phenomenal characters. This involves some departure from the most full-blooded first-order representationalism. Still, these features seem to qualify and depend on the representational features (as the slowness of a run depends on its being a run), so that representational properties still end up fundamental to consciousness.

Second, for some phenomenal characters, the core claim of the phenomenological case for first-order representationalism is not especially contentious: for instance, when one sees an X before one, arguably, first-person reflection on the experience reveals it to be successful as an experience if and only if representationally correct if and only if something X-shaped is before one. (Still, this is contested: perhaps first-person reflection reveals only a non-representational visual 'taking in' of or 'acquaintance with' an X; Travis 2004.) By contrast, for other phenomenal characters, the representational theory of perspective does not seem to be a natural fit. A visual experience in which nothing even seems to be seen—such as a visual experience with closed eyes—does not clearly involve any representation of anything; but it may seem to involve a non-representational perspective on something—a field suffused with a sort of 'blackness' (Hellie 2006).

Third, the '*inverted spectrum' threatens first-order representationalism. Very briefly, the issue is this: (1) plausibly, there could be a subject Abnorm who has the same phenomenal character when seeing green as the rest of us have when seeing red, and vice versa. This need not interfere with Abnorm's ability to navigate his environment. But if not, we should assume Abnorm correctly represents the colours of things. But then (2) there need be no difference between the representational properties of the experiences of Abnorm and of a normal subject when seeing certain scene, despite the evident difference in their phenomenal characters. But then it seems that phenomenal character varies independently of representational properties, against first-order representationalism. The literature contains a very extensive discussion of attempts to block (1) (Tye 2000, Lycan 2001) and (2) (Chalmers 2005, Shoemaker 2006).

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rubber hand illusion. People can be induced to have the experience that a rubber hand is their own hand. This is achieved by brushing a visible rubber hand and synchronously brushing a participant's real hand (Botvinick and Cohen 1998). In the experiment the participant's real hand is hidden out of view (behind a screen), while a realistic life-sized rubber hand is placed in front of the participant. The experimenter uses two small paintbrushes to stroke the rubber hand and the participant's hidden hand, synchronizing the timing of the brushing. After a short period (about 10–30 s in most cases), the majority of people have the experience that the rubber hand is their own hand and that the rubber hand senses the touch of the paintbrush. This *illusion is only evoked if the experimenter applies synchronous brush strokes to the real and fake hand. If the brush strokes are applied asynchronously, the person does not experience any sense of ownership towards the rubber hand. Similarly, the illusion only works well if the rubber

rubber hand illusion

hand is aligned with the participant's real hidden hand so that it visually appears to be the real hand. If the rubber hand is rotated 90–180° the illusion is not elicited even if synchronous brush strokes are applied to the two hands. These observations suggest that the illusion of ownership of the fake hand depends on the detection of synchronous visual and tactile events and the match between the seen and perceived orientation of the arm.

The rubber hand illusion is a vivid and strong perceptual illusion that can be evoked in most human participants. However, some people are resistant to the illusion for reasons that have not yet been studied. When a person experiences the illusion, they genuinely feels that the rubber hand is part of their body. For example, people will typically report that they expect the rubber fingers to move when they make a finger movement. Also, people will flinch if the experimenter threatens to injure the rubber hand, but only during the illusion. Such physical threats to the owned rubber hand is associated with increases in skin sweating, which is indicative of autonomic arousal (Armel and Ramachandran 2003), and activation of areas in the emotional system related to anxiety and pain anticipation (Ehrsson et al. 2007). Likewise, after having experienced the rubber hand illusion of their left hand, subjects make a reaching error (toward the location of the rubber hand) when asked to point toward their hidden left hand (Botvinick and Cohen 1998). These observations indicate that the artificial hand becomes incorporated into the body representation during the illusion.

The phenomenon that artificial limbs can be perceived as part of one's own body was probably first observed by Tastevin in 1937. This author reported anecdotally that people tend to attribute proprioceptive sensations to a seen rubber finger when the real finger was out of view (Tastevin 1937). This phenomenon, and the rubber hand illusion as described in modern times (Botvinick and Cohen 1998), belongs to a class of body illusions that are evoked by providing conflicting sensory information to different sensory channels. In the rubber hand illusion the brain has to reconcile the conflicting visual, tactile, and position sense information. This conflict is probably resolved by a recalibration of position sense of the real hand and changes in peripersonal space from the location of the real hand to the rubber hand (Botvinick and Cohen 1998; Ehrsson et al. 2004). This illusion demonstrates the malleability of the *body representation, and how this dynamic representation is continuously updated by the integration and interpretation of sensory information from all modalities.

The rubber hand illusion is important because it provides neuroscientists with a tool to probe the neural mechanisms of body ownership. This illusion suggests that a match between visual, tactile, and proprioceptive signals is sufficient to cause changes in the feeling of ownership of a limb. This is an observation of fundamental importance because it provides empirical evidence for the hypothesis that the self attribution of body parts is mediated by a match between somatosensory and visual information from the body (Bahrick and Watson 1985). Neurophysiological support for this hypothesis was recently obtained by Ehrsson et al. (2004) who used *functional brain imaging (fMRI) to scan the brain activity of participants while they perceived the rubber hand illusion. These authors found that the illusory feeling of ownership of the rubber hand was associated with increases in activity in multisensory brain areas, such as the premotor and parietal cortices, and that this activity correlated with the strength of the illusion.

An interesting question for future studies is how the owned rubber hand differs from hand-held tools. During tool use tactile sensations are projected from fingertips to the tip of the tool (Gibson 1966). You can try yourself when holding a pen and touching a piece of paper! As described above, the rubber hand illusion also involves the projection of touch from the real hand to the rubber hand. So what is the difference? Indeed, it has also been argued that tools becomes incorporated into the body representations after extensive tool use (as say the tennis racket of a professional tennis player), and that this could involve dynamic changes of the receptive field properties of visuo-tactile neurons on multisensory areas (Maravita and Iriki 2004). However, phenomenologically we do not experience tools as part of our own body, and few of us would mistake a hammer for our own hand, or be anxious if it was threatened by a sharp object. Speculatively, the rubber hand illusion involves changes in interoceptive systems such as proprioception and homeostatic emotional areas that do not take place in tool use.

There are also interesting links between rubber hand illusion and *phantom limb phenomena, in particular the treatment of phantom limb pain using so-called *mirror therapy (Ramachandran and Hirstein 1998). Mirror therapy is based on the idea that visual information can change the central proprioceptive representation of a missing limb (the phantom). The amputee puts his stump behind a mirror and places his normal arm in front of the mirror. The amputee then sees the mirror reflection of the intact arm superimposed on the phantom limb, which often elicits an illusory experience of 'seeing the phantom' (Ramachandran and Hirstein 1998). This has been reported to reduce phantom limb pain in pilot trial studies. Relevant for our discussion here is that the rubber hand illusion similarly depends on interactions between vision and proprioception. It might therefore be used in future research on modulation of the phantom limb experience and phantom limb pain.

The feeling of ownership of limbs is a fundamental aspect of human self-consciousness. Although philosophers and psychologists have been discussing the problem of the bodily self for centuries, it is only recently that neuroscientists have begun to study this question. The rubber hand illusion is particularly important in this respect because it provides cognitive neuroscientists with a tool to experiment with the body self in the laboratory setting. The subjective, behavioural, and neuronal correlates of this body-ownership illusion are relevant to the neuroscientific study of the self.

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