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Beyond body experiences: Phantom limbs, pain and the locus of sensation

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ABSTRACT

Reports of perceptual experiences are found throughout history. However, the phenomena considered worthy of note have not been those that nurture our survival (the veridical features of perception) but the oddities or departures from the common and commonplace accuracies of perception. Some oddities (like afterimages) could be experienced by everyone, whereas others were idiosyncratic. Such phenomena were often given a paranormal interpretation before they were absorbed into the normal science of the day. This sequence is examined historically in the context of beyond body experiences or phantom limbs. The experience of sensations in lost body parts provides an example of the ways in which novel phenomena can be interpreted. The first phase of description probably occurred in medieval texts and was often associated with accounts of miraculous reconnection. Ambroise Paré (1510–1590) initiated medical interest in this intriguing aspect of perception, partly because more of his patients survived the trauma of surgery. Description is followed by attempts to incorporate the phenomenon into the body of extant theory. René Descartes (1596–1650) integrated sensations in amputated limbs into his dualist theory of mind, and used the phenomenon to support the unity of the mind in comparison to the fragmented nature of bodily sensations. Others, like William Porterfield (ca. 1696–1771), did not consider the phenomenon as illusory and interpreted it in terms of other projective features of perception. Finally, the phenomenon is accepted and utilized to gain more insights into the functioning of the senses and the brain. The principal features of phantom limbs were well known before they were given that name in the 19th century. Despite the puzzles they still pose, these phantoms continue to provide perception with some potent concepts: the association with theories of pain has loosened the link with peripheral stimulation and emphasis on the phenomenal dimension has slackened the grip of stimulus-based theories of perception. The pattern of development in theories of phantom limbs might provide a model for examining out-of-body experiences (OBEs).

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> ''Many persons with lost limbs still seem to feel them in their old place. This illusion is so well known, and the material for study is so abundant, that it seems strange that no more systematic effort to investigate the phenomenon should have been made.''
>
> (James, 1887, p. 249)

1. Introduction

In the context of perception, the paranormal can be considered as what is beyond common sensory experiences. This definition has the advantage of excluding illusions that can be experienced by everyone. For example, what we now call afterimages can be seen following observation of a very intense light. As Aristotle noted, ''after having looked at the sun or some other brilliant object, we close our eyes, then, if we watch carefully, it appears in a right line with the direction of vision (whatever this may be), at first in its own colour; then it changes to crimson, next to purple, until it becomes black and disappears'' (Ross, 1931, p. 459b). This 'flight of colours' can be seen by most people, it can be interpreted in terms of modern visual science, and it would not be considered as paranormal. However, there are still problems with this simple definition, and they involve individual differences in experience. Colour blindness can be used as an illustration. Differences in the ability to discriminate the range of colours appeared remarkably late in the history of vision (see Wade, 1998), and it was restricted to a small number of individuals. It was not considered to be paranormal because a body of data and theory existed regarding colour vision, and colour blindness (better referred to as colour deficiency) could be accommodated within it.

This indicates that aspects of perceptual experience that are beyond the normal can be examined appropriately only after the normal characteristics of perception have been established. The natural operation of the senses and perception require to be appreciated, at least implicitly, before departures from this scheme can be assessed and analysed. There has been a long descriptive history of perceptual phenomena before theories were formed and experiments were performed. Thus, it is possible to chart the phases through which phenomena pass in progressing from description to dissection. It is only after an adequate phenomenal taxonomy is established that departures from normality can be suitably assessed and treated.

One class of phenomena often considered as paranormal has been variously called out-of-body experience (OBE), heautoscopy, and autoscopic hallucination – the impression that the whole body assumes spatial locations separated from its physical position (Blanke and Mohr, 2005; Brugger, 2002, 2006; Brugger et al., 2000; Dening and Berrios, 1994). Less extreme instances of experiences beyond the physical body are those in which sensations arise from regions that have been amputated or lost in some other way; they are frequently referred to as phantom limb phenomena. Like colour deficiency, these phenomena are experienced by a minority of the population, but there is a signal distinction between them. Beyond body experiences involve an addition to the normal range of perception rather than a depletion of it, perceptual gain appears to present more problems than perceptual loss. The former is more prone to be shrouded in the mantle of paranormal than the latter. In more conventional terminology, there is a greater readiness to relate loss of function to loss of structure than to interpret novel functions for which there is no evident structural equivalent.

It is in this context that beyond body experiences will be examined. It might seem a short step from beyond the body to being completely out of it, but the histories of their interpretations have differed radically. One possible reason for this relates to the issue of gain or loss: those who have lost a limb but experience sensations in the missing part can readily be identified. They have a physical loss and a perceptual gain. This does not apply to those describing OBEs: there is no physical distinction that can be applied to them, only the perceptual one. Both sets of phenomena can be interpreted in supernatural terms, but phantom limbs have proved more amenable to incorporation within the body of normal science. In each instance, the experiences have the characteristics of defying belief. The sensations that appear to be located in the severed body part are compelling, and these have been a concern of students of perception ever since they were clearly described in the 16th century. Examining the historical course of explanations for beyond body experiences might prove instructive for other phenomena that have similarly defied description within the normal science of the day.

The term 'phantom limb' was coined by Silas Weir Mitchell (1829–1914) (Mitchell, 1871). He treated injuries received by soldiers during the American Civil War, and set up a 'Stump Hospital' in Philadelphia for the many amputees. Mitchell (1866) wrote an anonymous and fictional account of one, George Dedlow, who had lost both arms and both legs. Due to the interest that the story generated, Mitchell (1871, 1872) wrote more serious accounts in which he described the sensations that amputees experienced in their lost limbs. After considering many possibilities he called the condition 'phantom limb', and this is the label that it still carries, despite its absence of conventional medical associations (Price and Twombly, 1972). As is the case for many phenomena, their discovery is associated with the process of naming rather than with that of their initial description. Numerous cases had previously and have since been reported, and phantom limbs continue to pose some perplexing problems for theories of perception. Most reviews of the phenomenon have been placed in a medical historical context, whereas here the focus will be directed to the history of the senses and theories concerning perception in general. Moreover, emphasis will be placed on 18th and 19th century reports that have been overlooked in histories of the phenomenon.

Damage or loss of one of the four main senses results in the absence of experiences formerly associated with their function. Blindness and deafness are particularly clear examples. But the sense organs for seeing and hearing – the eyes and ears – are localised in the head, and specialized receptors for light and sound are not found in other regions of the body. The skin senses are necessarily diffuse, and the consequences of loss are quite unlike those for the localised senses. One of the reasons why beyond body experiences were considered beyond normal perception was because the two principal

experiences associated with them, pain and touch, were either not considered to be sensory (pain) or fitted uneasily into the classical divisions of the senses (touch). Accordingly, their place in the scheme of the senses is worthy of examination in a historical context.

2. Classification of the senses

Aristotle stated that there were five, and only five, senses. These were sight, hearing, smell, taste, and touch. The sources of evidence available to Aristotle (and to those who followed him over the next 2000 years) for distinguishing between the senses were phenomenology and gross anatomy. They could report on their perceptual experiences when stimulated, and they could relate them to parts of the body evidently responsive to the stimulation. For example, sight ceased when the eyes were closed. Additional inferences could be drawn from disease or injury as well as from developmental disorders. Recourse was made to philosophy, usually linking the senses to the elements – fire, earth, water, and air – which permeated perception (Beare, 1906). The classical accounts of the senses drew principally upon psychological (or behavioural) evidence for their independence. In contrast, developments in the last few centuries have relied increasingly on anatomical and physiological indications of separate senses, and the behavioural dimension has been given less prominence (Wade, 2003a).

Aristotle did entertain the possibility of errors (illusions) entering into a particular sense. The examples he mentioned were those of colour or sound confusion and errors in spatial localisation of colours or sounds. Illusions are often considered to be a modern preoccupation, based on specific theories of perception, but their origins are ancient and illusions can be investigated with little in the way of theory. If there is an assumption of object permanence, then an illusion occurs when the same object appears to have different properties (of colour, position, size, shape, motion, etc.) under different circumstances (Wade, 2005a). The illusions so considered were minor variations from the normal and would have been assumed to be universal. More major departures from normal perception, particularly when they were confined to certain individuals, would not have been encompassed by such a scheme.

Touch has presented more problems than the other senses because its sensitivity is not localised to a particular sense organ, and the experiences derived from stimulating the skin are diverse. Pain, the other sense salient to phantom limbs, was missing. Touch and pain were both problematical in terms of classifying the senses, although the ways they were treated differed radically. Touch was taken as the exemplar of all senses because it so obviously involved contact between the skin and the source of stimulation. Pain was given less prominence and it was not included in the list of Aristotle's 'common sensibles' which were defined by properties of the stimulus rather than of sensation. For Aristotle, no obvious stimulus could be assigned to pain, other than over-stimulation or damage to the other senses, and so it was placed in opposition to pleasure rather than associated with the senses (Dallenbach, 1939).

Neither touch nor pain could be localised in a particular sense organ. Aristotle confronted this in the context of touch but not of pain: ''In dealing with each of the senses we shall have first to speak of the objects which are perceptible by each.... I call by the name of special object of this or that sense that which cannot be perceived by any other sense than that one and in respect of which no error is possible; in this sense colour is the special object of sight, sound of hearing, flavour of taste. Touch, indeed, discriminates more than one set of different qualities. Each sense has one kind of object which it discerns, and never errs in reporting that what is before it is colour or sound (though it may err as to what it is that is coloured or where that is, or what is sounding or where that is). Such objects are what we propose to call special objects of this or that sense. 'Common sensibles' are movement, rest, number, figure, magnitude; these are not peculiar to any one sense, but are common to all'' (Ross, 1931, p. 418b).

The other encumbrance to advance was ignorance of both the anatomy and physiology of the senses, let alone of the brain. Indeed, for Aristotle sensation was housed in the heart. Particularly large strides in understanding the senses and nervous function were made in the 19th century (Brazier, 1988; Finger, 1994). The gross anatomy of the brain was clarified, and its microanatomy was subjected to achromatic scrutiny; the cell and neuron doctrines were advanced; function was related to structure, initially fancifully (and phrenologically) and later with surgical precision; and a wide range of cognitive dysfunctions were linked with abnormalities in brain structures. It is the period between these two states that will be examined in the context of beyond body experiences.

Touch was often taken as the most important sense and the one relative to which others could be related. Aristotle stated: ''The primary form of sense is touch, which belongs to all animals'' (Ross, 1931, p. 413b). It is perhaps for this reason that Aristotle maintained that touch is a single sense, that the number of senses is restricted to five, and that: ''there cannot be a special sense-organ for the common sensibles either'' (p. 425a). Boring's conclusion about this dogma was clear: ''It was certainly Aristotle who so long delayed the recognition of a sixth sense by his doctrine that there are but five senses'' (Boring, 1942, p. 525). For Boring, as for most other historians of the senses, the additional one that emerged in the early-19th century was the muscle sense, although many subdivisions of touch had been proposed in previous centuries (Hamilton, 1846).

With advances in anatomy and physiology in the 20th century, additional criteria emerged for separating the senses: quality of the experience, nature of the stimulus, gross and microanatomy of the receptor system, and pathways to and representation on the cortex (Neff, 1960). The psychological dimension is the oldest of these, and yet less attention has been paid to behavioural evidence for distinguishing and adding to the senses than to that derived from anatomy and physiology. On the basis of these criteria there are many more than five senses and pain is included amongst them. Nonetheless, as Dallenbach (1939) remarked, ''The testimony of the ages proved ineffectual in refuting the Aristotelian doctrine of the senses'' (p. 335).

3. Phantom limbs

Although Mitchell (1871) gave the phenomenon its name, reports of phantom limbs were made long before the American Civil War. Reporting experiences from amputated parts has an extensive history, but it remains remarkably short considering the incidence of the condition (see Halligan, 2002). The experience of sensations in lost limbs also provides an example of the ways in which novel phenomena can be interpreted. In this instance, the first phase is a description of the phenomenon. This is followed by attempts to incorporate it within extant theory. Finally, the phenomenon is accepted and utilized to gain more insights into the functioning of the senses (Table 1). In many cases, the phenomena have been described in antiquity, and no clear origin can be determined. In others, there is an obvious break with the past and a phenomenon is described and investigated for the first time. Many phenomena are named after the first person considered to have described them. The clarity of a succinct label frequently blurs the detailed natural history of phenomena, and such is certainly the case for phantom limbs.

Initially, phenomena are described in a general way, often incorporating elements of the putative cause. The phenomenology is thereafter refined, and perhaps subdivisions of the phenomena are introduced. During this phase they can acquire a variety of names that bear some relationship to the nosology of the day. Many of the 17th and 18th century writers referred to the experiences as 'pain of an amputated limb' that was 'erroneous', 'deceptive', 'imaginary', or 'paradoxical' (Price and Twombly, 1972). Once clearly described the experiences are typically placed within some theoretical framework. This often involves its classification as supernatural or illusory.

Beyond body experiences were of interest to Ambroise Paré (1510–1590; Fig. 1, left) because they were considered to be illusory. They had the additional aspect of theoretical intrigue because they could not be associated with stimulation of the region in which the experience was located; that is, the experience was beyond the physical body parts. Thus, the issue of the locus of sensation moved to centre stage. When the brain was implicated in the experience, the relationship between sensation and nervous action was deliberated upon. With acceptance of both the phenomenon and its possible neural basis, its characteristics can be used to support particular theories of brain function.

Table 1 – A natural history of sensory phenomena indicating the phases through which their investigation can pass

Data	
Description	Phenomenology
Confirmation	Refining phenomenology
Naming	Often eponymous
Theory	
Interpretation	Location of sensation – peripheral or central? Illusion or reality?
Integration	Within extant knowledge of nervous function
Exploitation	Phenomena used to support particular theoretical ideas

3.1. *Phase 1 – Data*

The first phase of understanding any phenomenon is an adequate description of it. This can occur independently of theory, but the phenomena are rarely free from the psychological spirit of the times. The latter often intrude on the phenomenology so that a clear description remains difficult to extract. This is certainly the case for beyond body experiences. Evidence of loss of limbs, through disease, accident, warfare, or ritual has been commented upon since records began and illustrations of such cases were commonplace (Price and Twombly, 1978). Amputation is one of the oldest surgical procedures (Sachs et al., 1999) and prosthetic devices have been in widespread use for millennia (Padula and Friedmann, 1987). However, despite this long history of limb loss and the folklore associated with miraculous reconnections, the first descriptions of the phenomena did not appear until the 16th century. The experience of sensations in an amputated body part is considered to be near universal (Sherman et al., 1984) and so the absence of early descriptions is remarkable. Price and Twombly (1978) have examined 75 accounts of medieval miracles regarding lost limbs; these reduced to multiple accounts of five cases, all of which have some features, often tenuous, in common with phantom limb experiences. This dearth of data might have resulted from treating the cases in terms of the miraculous rather than the medical. The accounts would have been recorded in a religious context, with emphasis on loss and reconnection rather than recovery. It is with the emergence of medical practices in the Renaissance that observation rather than religious observance provided the data on which theory could be built.

Paré (1551) made great strides in the surgical treatment for amputation; he applied ligatures to the large vessels in the limbs to staunch the bleeding following amputation and he applied tourniquets above the site of severance. As a consequence of his improved surgical techniques, more of Paré's amputees survived. He described many such operations and the procedures that can be adopted in order to increase the likelihood of post-operative survival. Indeed, Paré (1575, 1649) described and illustrated a wide range of prostheses that could be used after amputation (Fig. 1). These included mechanical hands, arms, and legs, all with moveable parts. He not only performed the operations, but followed the progress of patients following amputation. In his *Apology* (Paré, 1951), he devoted a chapter to amputations, indicating the signs necessitating it, and the procedures for conducting the operation. The most common cause for the operation was gangrene. Paré noted that the gangrenous extremity was bereft of sensitivity, and yet might still respond to pricking. He realized that this could indicate a false sensitivity in the affected part, and might retard operation. He then related such feelings to those of phantom limbs: ''A most cleare and manifest argument of this false and deceiptful sense appears after the amputation of a member; for a long while after they will complaine of the part which is cut away. Verily it is a thing wondrous strange and prodigious, and which will scarce be

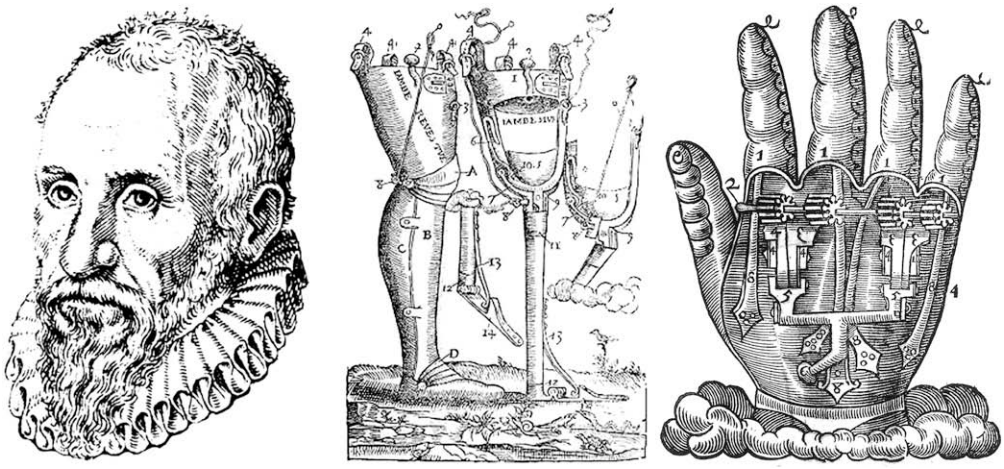


Fig. 1 – Left, a portrait of Ambroise Paré (1510–1590); centre, some intricate prosthetic legs, and right a mechanical hand (all images from Paré, 1649).

credited, unlesse by such as have seen with their eyes, and heard with their ears the Patients who have many months after the cutting away of the Leg, grievously complained that they yet felt exceeding great pain of that leg so cut off'' (Paré, 1649, p. 338). Paré speculated that the lingering sensations from the lost limb were a consequence of stimulating the nerves in the severed stump.

Much more was then known about the peripheral nervous system than about the brain, as was evident from Paré's diagrams (Paré, 1575, 1649; Fig. 2, left and centre). The prevailing belief was that the animal spirit flowed through the hollow nerves from the senses to the ventricles in the brain. Paré (1575, 1982) also described cases in which individuals had no arms (Fig. 2, right). It is not clear from his brief descriptions whether they were armless from birth, but he did describe the remarkable feats they could achieve despite the absence of their arms. Unfortunately, Paré did not remark on any sensations they reported in the absent members, which would have been of particular interest in the light of cases of people born without complete arms or legs but retaining sensations from the missing extremities (Brugger et al., 2000; Brugger and Funk, 2006; Melzack et al., 1997; Valentin, 1836; see Price, 2006, for a review of the cases). There is no explicit indication in Paré's description whether the losses had been present since birth, but this seems likely because they were not discussed in his books on surgery and his accounts of

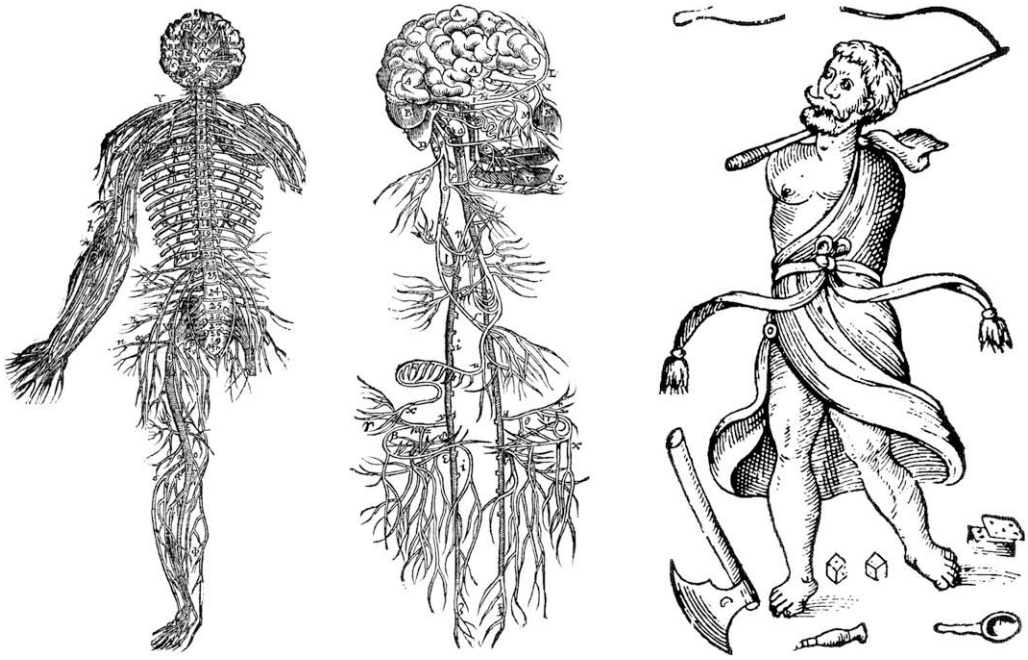


Fig. 2 – Left and centre, diagrams of the nervous system (from Paré, 1649). Right, Paré's (1575) depiction of an armless with an indication of the tasks he could perform.

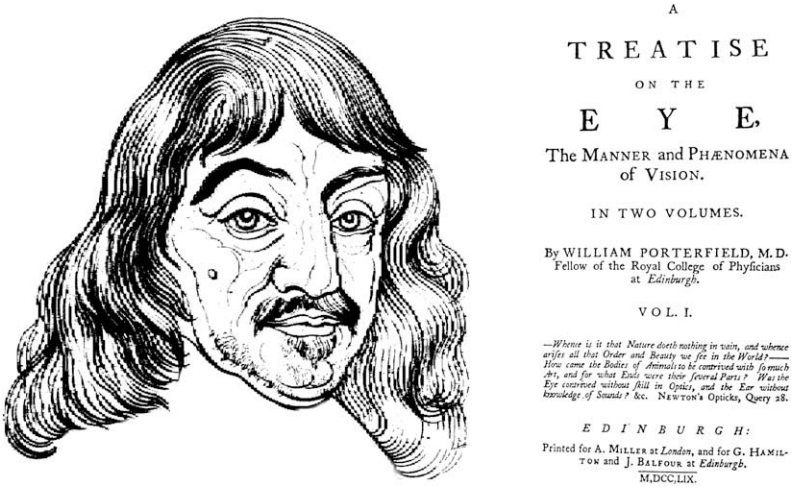
amputation. Moreover, the many other 'marvels and monsters' mentioned by him in the same chapter relate to anomalies of birth.

Paré's books were widely read and they were translated into several languages. By the time René Descartes (1596–1650; Fig. 3, left) was writing about the phenomenon it appears to have been common medical knowledge. Once attention had been drawn to experiences in amputated body parts then the phenomenology associated with them can be refined. However, such phenomenal refinement took place slowly. For example, James (1887) drew attention to individual differences in the phantom experiences as well as the postures in which the limbs were perceived and the apparent control over them. Nonetheless, his account was published in a journal of psychical research. Aspects like the localisation of beyond body sensations to the peripheral parts of the severed member (toes or fingers) and their restriction to unusual sensations (shooting, stabbing, tingling, tickling, burning and telescoping) emerged gradually (Price and Twombly, 1972; Ramachandran and Hirstein, 1998; Sherman and Sherman, 1983).

3.2. *Phase 2 – Theory*

Beyond body experiences were not only described but also integrated with prevailing theories of perception from an early stage. This second phase was present in Paré's initial accounts, where he localised the feelings in stimulation of the severed stump nerves. Theoretical speculations were taken further by Descartes. In his book on optics, Descartes (1637/1902) argued that all sensation is located in the brain rather than in the sensory organs themselves. Objections to this view were expressed by some of Descartes's correspondents, and he responded by commenting on reports of sensations in amputated limbs; they were used as evidence that all sensations take place in the brain. In subsequent letters concerning such sensations, Descartes (1991) attributed them to activity in the brain normally associated with the missing limb. In addition, Descartes considered that the phenomenon indicated the unreliability of the senses: ''Although the whole mind seems to be united to the whole body, I recognize that if a foot or arm or any other part of the body is cut off, nothing has thereby been taken away from the mind'' (Descartes, 1984, p. 59). Thus, Descartes was echoing the Platonic distrust of the senses.

Early reports of phantom limbs relied on the amputees relating their experiences to physicians or surgeons; that is, they were second-hand descriptions. Other writers used the distilled medical reports as the sources of their own analyses. Most of the amputees had little prior medical experience, and the accuracy of their account was often dependent upon the literary skill of the surgeon (Finger, 1994; Finger and Hustwit, 2003; Price and Twombly, 1972, 1978; Wade, 2003b; Wade and Finger, 2003). This was not the case for William Porterfield (ca. 1696–1771) (Porterfield, 1759), who was able to give a first-hand account of his own phantom leg in his *Treatise on the Eye* (Fig. 3, right). His description emphasised the dimension of pain and its localisation: ''Having had this Misfortune myself, I can the better vouch the Truth of this Fact from my own Experience; for I sometimes still feel Pains and Itchings, as if in my Toes, Heel or Ancle, &c. tho' it be several Years since my Leg was taken off. Nay, these Itchings have sometimes been so strong and lively, that, in spite of all my Reason and Philosophy, I could scarce forbear attempting to scratch the Part, tho' I well knew there was nothing there in the Place where I felt the Itching. And, however, strange this may appear to some, it is nevertheless no way miraculous or extraordinary, but very agreeable to the usual Course and Tenor of Nature'' (Porterfield, 1759, p. 364). He displayed considerable sophistication in the analysis of his phantom limb, by associating the projective features of the experience with other aspects of perception. He was well-versed in contemporary colour vision theory, and cited Newton's statement that the rays are not coloured but that the experience of colour is subjective. Porterfield was extending this subjectivity of sensation to phantom limbs, and incorporating the sensations into the body of perceptual theory. A similar relationship is drawn for the visual perception of direction, an aspect of spatial vision that exercised Porterfield considerably (Wade, 2000a). He did not regard the experiences of the lost limb as phantoms, but as a natural consequence of stimulating the



A
TREATISE
ON THE
EYE,
The MANNER and PHÆNOMENA of VISION.
IN TWO VOLUMES.
By WILLIAM PORTERFIELD, M.D. Fellow of the Royal College of Physicians at *Edinburgh*.
VOL. I.
—*Whence is it that Nature doth nothing in vain, and whence arises all that Order and Beauty we see in the World?—— How came the Bodies of Animals to be contrived with so much Art, and for what Ends were their several Parts? Was the Eye contrived without Skill in Optics, and the Ear without knowledge of Sounds?* &c. NEWTON's Opticks, Query 28.
EDINBURGH:
Printed for A. MILLER at *London*, and for G. HAMILTON and J. BALFOUR at *Edinburgh*.
M,DCC,LIX.

Fig. 3 – Left, René Descartes (1596–1650) after a portrait in Lavater (1799). Right, the title page of Porterfield's *Treatise*.

brain in a manner similar to that which existed prior to amputation. By comparing touch to vision, he integrated the phantom limb experiences with his general theory of perception.

This position was accepted by many physicians in the 18th century. For example, in his textbook on medicine, George Fordyce (1736–1802) (Fordyce, 1771; Fig. 4, left) related phantom sensations to the normal functioning of the nervous system. A similar sentiment, voiced again with primary reference to the nerves and their pathways, was written in the next decade by John Hunter (1728–1793) (Hunter, 1786; Fig. 4, right). These examples were of particular significance as both Fordyce and Hunter considered that all senses responded to touch and pain, in addition to their specific sensations. In his papers, which were not published during his lifetime, Hunter (1861) expressed it thus: ''Touch is probably the only sense that is cognizable by another sense besides the immediate sensation'' (p. 7). That is, if touch alone was experienced as a phantom sensation, then it might reflect the central operation of common sensitivity. If the specific sensations associated with a particular body part could be experienced after amputation then that was stronger evidence for the localisation of sensation in the brain. Moreover, in the cases described the sensations in the lost member (the penis) involved pleasure rather than pain. Others were able to corroborate the reports gathered by Hunter. Andrew Marshal (1742–1813) (Marshal, 1815; Fig. 5, left) also noted the effects of loss of the penis, and related it to the other senses.

An alternative theoretical approach was taken by Erasmus Darwin (1731–1802; Fig. 6, left). His analysis was greatly influenced by Berkeley's (1709) empiricist theory of perception. Darwin (1794) speculated about sensations in a lost limb and suggested that the motor and the sensory system were involved: ''the ideas of the shape, place, or solidity of the lost limb, return by association; as these ideas belong to the organs of sight and touch, on which they were first excited'' (p. 28). His interpretation was questioned by a close family friend, Tom Wedgwood (1771–1805; Fig. 5, right). Only a fragment of Wedgwood's writings has been published, and parts of his 'Essay on vision' were included in an anonymous compilation (Anon, 1817, reprinted in Meteyard, 1871). Phantom limb phenomena took on personal significance for both Darwin and Wedgwood because Tom's father, Josiah Wedgwood (1730–1795; Fig. 6, right), had a leg amputated three years before Tom was born, and Darwin was Josiah's physician.

It would seem that Josiah experienced sensations from his missing leg, as one of his biographers wrote: ''Yet, for many years, the severed nerves continued to convey sensations to the brain or to the nervous system which had been affected, so that he continued to feel the remains of the pain in what he called his 'no-leg'' (Smiles, 1894, p. 121). Darwin related the phantom sensations to prior sensory–motor associations, whereas Tom Wedgwood used the experiences to cast doubt on the primacy of touch as advocated by Berkeley. Wedgwood's theory was also based on Hartley's (1749) notions of association, and he believed that associations could be forged between visual ideas themselves (Wade, 2005b). The occurrence of phantom sensations in a missing limb was taken as evidence that touch was not primary: ''A person who has lost a hand, often fancies that he feels pain in a finger of that hand, and refers it to that place in the air which his finger would have occupied if he had not lost it. Nothing can more incontestibly prove the inadequacy of touch to mark position, since the touch or pain is here supposed to suggest its having position in a place where there is no part of the body existing'' (Anon, 1817, pp. 5–6).

Yet further fuel for this philosophical fire was provided a decade later by Charles Bell (1774–1842; Fig. 7, left) who also referred to sensations in a lost penis (Bell, 1811/2000). Bell made recourse to phantom limb sensation to support his view that the seat of sensation is in the brain. Both Bell and Johannes Müller (1801–1858; Fig. 7, right) employed phantom limb phenomena in support of the concept of specific nerve energies. Müller (1837, 2003) provided descriptions of

Fig. 4 – Left, George Fordyce (1732–1802) after a portrait in the Medical Society of London. Right, John Hunter (1728–1793) after a frontispiece portrait in Hunter (1861).

Fig. 5 – Left, Andrew Marshal (1742–1813) after a frontispiece silhouette in Marshal (1815). Right, a negative portrait of Tom Wedgwood (1771–1805) derived from a frontispiece photograph of a chalk drawing in Litchfield (1903). Wedgwood produced the first negative camera images.

13 cases of sensations following amputation. His summary of the effects of amputation is astute: ''*When a limb has been removed by amputation, the remaining portion of the nerve which ramified in it may still be the seat of sensations, which are referred to the lost part*…. These sensations are not of an undefined character; the pains and tingling are distinctly referred to single toes, to the sole of the foot, to the dorsum of the foot, to the skin, &c. These important phenomena have been absurdly attributed to the action of the imagination, &c. They have been treated merely as a curiosity; but I have convinced myself of their constancy, and of their continuance throughout life, – although patients become so accustomed to the sensations that they cease to remark them. The feeling of tingling or creeping of ants in the hand, foot, or whole extremity, with the same distinctness as when the limb is still present, may be excited much more vividly by applying a ligature or tourniquet to the stump, or by exerting pressure on its nerves; hence patients have the feeling of their lost limb most distinctly, when from any cause the application of the tourniquet is again necessary. If the patient have suffered before amputation from a local painful affection of the limb, the whole limb will still be felt as if in pain after its removal;

Fig. 6 – Left, Erasmus Darwin (1731–1802) and right, Josiah Wedgwood (1730–1795), both after engravings in Meteyard (1865).

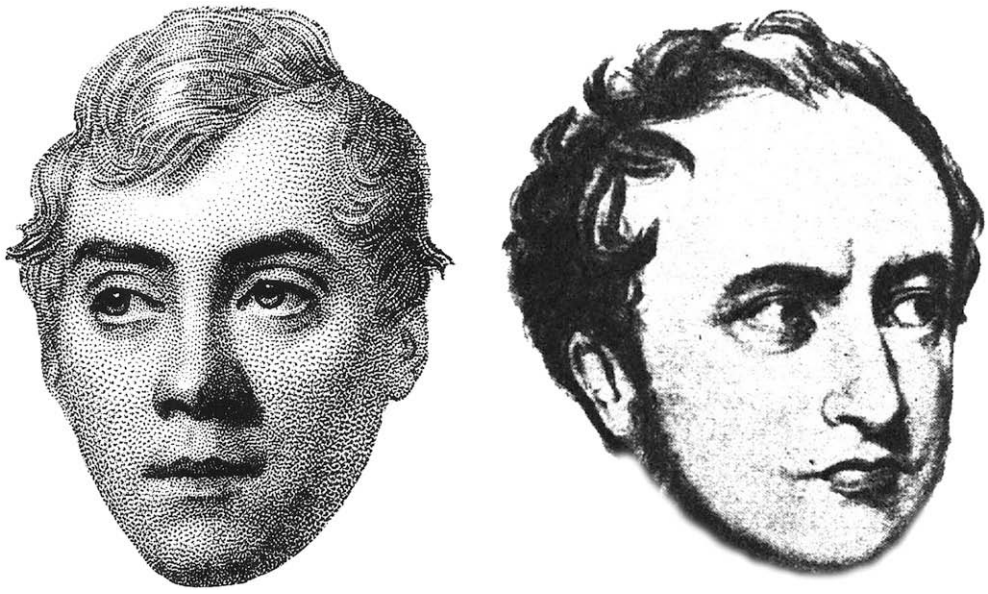


Fig. 7 – Left, Charles Bell (1774–1842) after a frontispiece engraving in G. Bell (1870). Right, Johannes Müller (1801–1858) after a portrait in Hirsch (1929).

and pain will be felt as if in the whole limb, at the moment when the nerve is divided, and during inflammation of the stump'' (Müller, 2003, pp. 745–746, original italics).

Müller's claim that the experience of phantom limb sensations in amputees is universal has generally been supported, although Mitchell (1872) found that 86 of 90 cases he examined reported sensations in the missing limb. These features make the absence of reports before Paré even more surprising. Limbs have been amputated because of damage or disease for millenia, and some must have survived the trauma of amputation to experience these enigmatic feelings. Moreover, the common feature of reports is the existence of localised pain in the severed part; other sensations associated with the skin and muscles (like being touched, temperature sensitivity or movement) have not been so commonly reported.

Phantom limbs have been accorded serious theoretical attention because they can potentially be accommodated within the confines of contemporary neuroscience. To return to an issue raised in the introduction, they incorporate elements of physical loss and perceptual gain: the sensations in the missing body parts can be related to those that were experienced before the loss. This view sits uneasily with sensations reported in limbs that never developed. Such cases of aplasic phantoms cannot be related so readily to the consequence of past experience (Brugger and Funk, 2006; Price, 2006). They are an instance in which perceptual gain is reported in the absence of loss. Supernumerary limbs lie in a similar theoretical limbo, although they are usually associated with prior pathology (Halligan et al., 1993; McGonigle et al., 2002). In these instances pain is not such a central feature as it has been in what might be called classical cases of phantom limbs.

There were many reports of phantom sensations in amputated limbs before Mitchell (1871) than have been reported above, but Mitchell himself did not draw upon them. Most adopted a peripheral interpretation of the beyond body experiences, although Porterfield (1759) emphasised the projective features of all perception, and Darwin (1794) associated touch closely with vision. All worked on the assumption that pain was not a sensation, but it is through pain that the phenomenon has been reinterpreted.

4. Pain and the locus of sensation

The pain associated with phantom limbs lent support to theories that restricted pain to peripheral tissue damage. Such specificity theories corresponded well with Descartes's (1664/1909) views on pain and its genesis. Although the concept of specialised receptors did not then exist, Descartes considered that the skin consisted of nerve endings; when these were overstimulated (as by fire), mechanical signals were transmitted via the animal spirit along the nerves to the brain, where pain was perceived. For Descartes, pain was not a sensation, nor was it to be for several centuries. The situation was to change with the discovery of cutaneous sensory spots in the 19th century (Norrsell et al., 1999; Wade, 2003a).

A division of the skin senses into three separate systems (one to register temperature, a second for pressure, and a third for touch) was proposed by Ludwig Natanson (1822–1871) (Natanson, 1844). He supported the contention of peripheral independence by describing how these systems succumb in sequence when a limb 'falls asleep'. Three sets of independent studies were reported in the 1880s by Magnus Blix (1849–1904), Alfred Goldscheider (1858–1935) and Henry Donaldson (1857–1938), and they are jointly credited with the discovery. All were principally concerned with establishing cold and warm spots. Blix (1884) continued in the tradition of applying low intensity electric currents to the skin; he found separate warm and cold spots (see Norrsell, 2000). Goldscheider (1884)

stimulated the skin with a range of devices, like needles, heated brass cylinders, cooled capillary tubes, and brushes coated with ether to isolate the cutaneous spots. Donaldson (1885) discovered the warm and cold sensory spots independently in the course of moving metal points slowly over the skin.

The sensory spots could be mapped on the skin surface and attempts were made to match them to receptors revealed by histological sections of excised skin. The transmission of signals from the specialised endings conformed well with Müller's doctrine of specific nerve energies. Towards the end of the century Max von Frey (1852–1932) (Frey, 1895) found that certain spots on the skin responded specifically in terms of pain and he advanced the theory that the sensations of warmth, cold, and pressure are subserved by specific end organs in the skin whereas pain receptors were free nerve endings. His theory was soon under attack on empirical and theoretical grounds (Dallenbach, 1939), but it hastened the incorporation of pain into the theatre of the senses. Sensory fibres of different diameter were found to serve different aspects of pain, and these were to provide the clue for a radical revision of theories of pain.

In contrast to specificity theory, Melzack and Wall's (1965) gate control theory of pain provided a physiological mechanism for central (psychological) control over pain experience. Moreover, Melzack (1990, 2001) has applied the extension of the theory (the neuromatrix) to phantom limb pain. While the phenomena continue to intrigue and excite students of the senses (Ramachandran and Rogers-Ramachandran, 1996; Ramachandran and Hirstein, 1998), they have provided the basis for transforming theories of pain from peripheral to central sites. They have similarly incorporated a seemingly paranormal phenomenon (beyond body experiences) into the body of normal science. Moreover, treatment procedures (like the mirror box) introduced in the context of phantom limbs are being used for a wider variety of pain relief (Ramachandran, 2005), although the extent of its benefits to phantom limb patients has been questioned (Brodie et al., 2007). Extensions of the mirror box techniques (like virtual immersion) also offer potential for pain relief by incorporating visual signals that would correspond to those from the missing limb (Murray et al., 2006).

Mirror boxes have been employed to provide visual stimulation that could correspond to that arising from a missing body part. Mirror studies have not been confined to cases with missing limbs. George Malcolm Stratton (1865–1957; Fig. 8, left) conducted a mirror experiment on himself in 1899: he observed a visual image of the whole body located beyond its physical constraints (Fig. 8, right). Stratton is best known for his earlier studies of vision with an upright retinal image (Stratton, 1897a, 1897b; Wade, 2000b), where he examined adaptation to inversion over a period of days. The mirror visual displacement of the whole body bears similarities with OBEs and thus might provide a conceptual and experimental bridge between phantom limbs and autoscopy. As was the case with inverting lenses, the adaptation to a relocalised body was a protracted process. Stratton wore the mirror device for three days and the impressions that his body was occupying the visual location were brief and sporadic: ''If I carefully noticed whether my body seemed to be in its older place, this older location could always be felt. But in the more languidly receptive attitude during my walk, I had the feeling that I was mentally outside my body. It was, of course, but a passing impression, but it came several times and was vivid while it lasted. But the moment critical interest arose, the simplicity of the state was gone, and my visible actions were accompanied by a kind of wraith of themselves in the older visual terms'' (Stratton, 1899, p. 496). Nonetheless, Stratton maintained that, given an adequate duration of visual

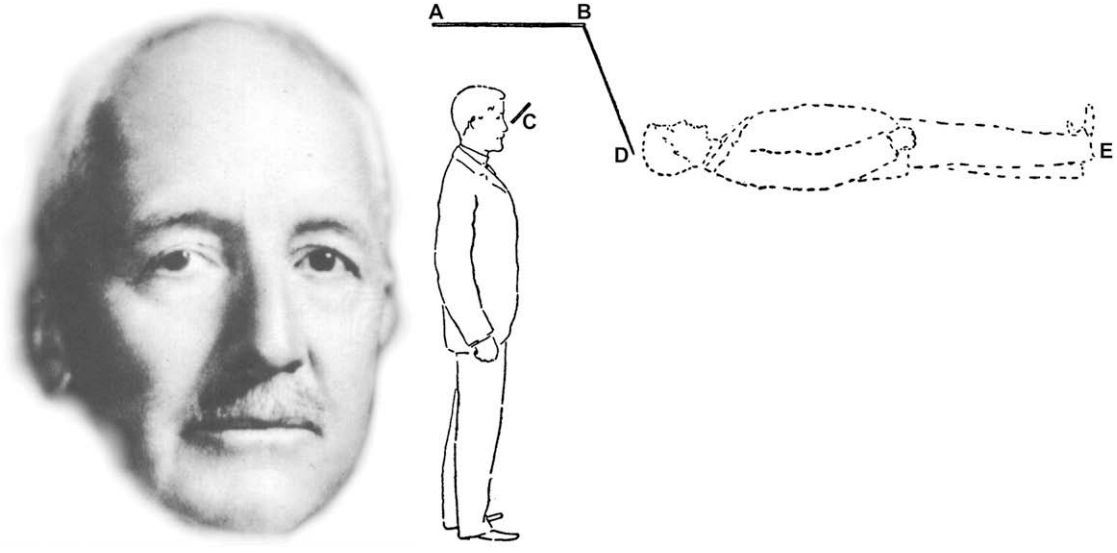


Fig. 8 – Left, George Malcolm Stratton (1865–1957) after a photograph kindly supplied by the University of California, Berkeley. Right, Stratton's diagram of his mirror device: ''A mirror (AB in the diagram) was supported horizontally and face downward over my head; and below this, and before my eyes, a small mirror (C) was fixed face upward but slanting at an angle of about 45°. The mirror overhead thus imaged the person as seen from above, and this image was in turn reflected in the mirror C, so that the observer saw his own figure projected in front of him, approximately in the position DE'' (Stratton, 1899, pp. 492–493).

Table 2 – A natural history of phantom limb research and the directions in which contemporary concerns are proceeding

History	
Description	Paré (1551)
Confirmation	Many 17th and 18th century surgeons
Naming	Mitchell (1871)
Theoretical interpretation	Paré (1551), Descartes (1637)
Theoretical integration	Porterfield (1759), Hunter (1786)
Theoretical exploitation	Bell (1811), Müller (1837), Melzack (1990), Ramachandran (1996)
Modern concerns	
Examination	Panoply of methods of modern neuroscience EEG, MEG, fMRI, TMS
Extension	Concerns with consciousness, body image, neural plasticity; from beyond the limb to out of the body
Exploration	Phantoms as metaphors in art and science

exposure to the new spatial relations: ''In whatever place the tactual impression's visual counterpart regularly appeared, this would eventually seem the only appropriate place for it to appear in'' (p. 498). Thus, it might prove profitable to examine the time course over which OBEs emerge.

Another pertinent feature emphasised by Stratton was the harmony between the senses: ''with the process by which the different sense–perceptions, whatever may be the ultimate source of their extension, are organised into one harmonious spatial system. The harmony is found to consist in having our experiences meet our expectations'' (Stratton, 1899, p. 504). Phantom limbs proved to be of medical interest because such harmony did not exist – the senses of vision and feeling were in conflict. Perhaps OBEs have been neglected for so long scientifically because no such obvious conflict was evident, although attention is being directed increasingly to aspects of vestibular–motor interaction (Cheyne and Girard, 2009, this issue). When normal phenomena, like Stratton's displacement of the seen body by means of mirrors, are compared to the various types of autoscopic phenomena, there might be grounds for removing the 'para' prefix from the latter.

Stratton's observations and assessments of his visually displaced body presaged theoretical issues that have come to the fore in recent research. OBEs involve a dissociation of the normal body schema and this has been discussed in the context of frames of reference (Cheyne and Girard, 2009, this issue; Easton et al., 2009, this issue; Terhune, 2009, this issue). Similar concepts have been introduced in studies of normal space perception (Wade, 1996; Wade and Swanston, 1996, 2001). Vision requires a geocentric frame of reference – one that represents objects in terms of their three-dimensional co-ordinates – in order to guide behaviour. A visual geocentric representation is based on prior mapping in terms of retinocentric and egocentric co-ordinates; the latter is based upon an origin within the body (like the egocentre or cyclopean eye for vision). Thus the egocentric frame of reference does not engage the processes (like vestibular function) which anchor the body to earth's gravity (Wade, 1992). Vestibular mechanisms are being implicated increasingly in interpretations of OBEs, and the dissociation between geocentric and egocentric representations of space could provide an avenue for future exploration.

5. Conclusion

The experiences associated with lost body parts continue to intrigue and excite us. There remain many ways of interpreting phantom limb phenomena, which are clearly concerned with memory: a current pattern of stimulation in the brain is associated with ones from the past, and similarities are experienced. The history of phantom limb research can be examined in much the same way as can that for other sensory phenomena (Table 2), and the study has recently been revitalised and extended to experiences beyond the former physical bounds of the body. This has been a consequence of several developments in the neurosciences. First, embracing pain into the theatre of the senses has acted to emphasise the role of central processes in perceptual function. Second, a range of non-invasive methods of brain stimulation and imaging has been applied to patients experiencing phantom limbs and these methods have augmented its relevance to current theories in neuroscience (see Bestmann et al., 2006; Flor et al., 2006). Third, phantom sensations are linked increasingly with other phenomena that reflect on the perception of the body and its location in space, like autoscopic phenomena and the experience of supernumerary limbs. That is, phantom limb phenomena can act as markers or metaphors for investigating processes underlying consciousness and neural plasticity. Ramachandran and Hirstein (1998) have argued: ''that a study of phantom limbs can provide fundamental insights into the functional organization of the normal human brain and that they can serve as markers for tracking neural plasticity in the adult brain'' (p. 1604). The extent to which they function as markers rather than metaphors will depend upon the results from behavioural, clinical, and neurological studies that lie in the future, as research on these topics is in its scientific infancy (Brugger, 2006).

It is evident that, despite the puzzles they still pose, the phantoms have provided neuroscience with some potent concepts and have assisted in understanding the relationship between perception and brain processes. The paths through which beyond body experiences have been integrated within contemporary neuroscience might well provide a model for other phenomena that were once considered beyond its scope. The locus of sensation has traditionally been concerned with differentiating between stimulation of peripheral sense organs and the signals relayed to the sensorium or brain. Emphasising the projective features of perception in general, as Porterfield (1759) so ably did in the context of his own phantom leg, refocuses the question: if our perception is projected beyond the brain then what are the constraints that limit its ambit?

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