CHAPTER

20

Leaving Body and Life Behind: Out-of-Body and Near-Death Experience

Olaf Blanke[1,2,3], *Nathan Faivre*[1,2], *and Sebastian Dieguez*[4]

[1]Laboratory of Cognitive Neuroscience, Brain Mind Institute, School of Life Sciences, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland [2]Center for Neuroprosthetics, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland [3]Department of Neurology, University Hospital, Geneva, Switzerland [4]Laboratory for Cognitive and Neurological Sciences, Department of Medicine, Hôpital de Fribourg, Université de Fribourg, Fribourg, Switzerland

OUTLINE

Out-of-body experiences (OBEs) and near-death experiences (NDEs) have accompanied and fascinated humanity since times immemorial and have long been the province of circles interested in the occult. Many authors have even argued that either experience provides evidence for the mind being separate or independent from processes in the body and brain or the persistence of life after death. The neurology of OBEs and NDEs takes a different—empirical and neuroscientific—stance studying the brain mechanisms that are associated behaviorally and neurally with these experiences. Accordingly, OBEs have been studied by neurologists and cognitive scientists investigating the functional and neural mechanisms of bodily awareness

S. Laureys, O. Gosseries & G. Tononi (Eds)
The Neurology of Consciousness, Second edition.

DOI: http://dx.doi.org/10.1016/B978-0-12-800948-2.00020-0

and self-consciousness in specific brain regions. In the present chapter we will review these recent neuroscientific data on OBEs. The situation is quite different for NDEs. Although many different theories have been proposed about brain processes, neurologists and cognitive neuroscientists have paid little attention to these experiences. This is unfortunate, because the scientific study of NDEs could provide insights into the functional and neural mechanisms of many facets of human experience such as beliefs, concepts, personality, spirituality, magical thinking, and self. Moreover, as we will review, there is a frequent association of OBEs and NDEs, to the point that they are frequently confused with each other or unwarrantedly cross-referenced (e.g., Formatting Citation). This is probably due to the fact that OBEs are often associated with NDE, if not one of the NDE key elements (Ring, 1982; Sabom, 1982; Moody, 2001). In the following, we will describe OBEs and NDEs, providing definitions, incidences, key phenomenological features, and reviewing some of the underlying psychological and neurocognitive mechanisms.

OUT-OF-BODY EXPERIENCES

Definition

In an OBE, people seem to be awake and feel that their "self," or center of experience, is located outside of the physical body (disembodiment). They report seeing their body and the world from an elevated extracorporeal location (Green, 1968; Blackmore, 1992; Brugger, 2002; Blanke et al., 2004; Bünning and Blanke, 2005). The subject's reported perceptions are organized in such a way as to be consistent with this elevated visuo-spatial perspective. The following example (Irwin, 1985, case 1) illustrates what individuals commonly experience during an OBE: "I was in bed and about to fall asleep when I had the distinct impression that "I" was at the ceiling level looking down at my body in the bed. I was very startled and frightened; immediately [afterwards] I felt that I was consciously back in the bed again." We have defined an OBE by the presence of the following three phenomenological elements: the feeling of being outside one's physical body (or disembodiment); the perceived location of the self at a distanced and elevated visuo-spatial perspective (or perspective); and the experience of seeing one's own body (or autoscopy) from this elevated perspective (Bünning and Blanke, 2005). In other proposed definitions of OBEs it suffices to experience disembodiment, and OBEs are thus defined as "experiences in which the sense of self or the center of awareness is felt to be located outside of the physical body" (Alvarado, 2000, p. 331; see also Alvarado, 2001) or as experiences in which "the center of consciousness appears to occupy temporarily a position which is spatially remote from his/her body" (Irwin, 1985). Another definition requires disembodiment and a distanced visuo-spatial perspective: "the feeling of a spatial separation of the observing self from the body" (Brugger, 2002). OBEs constitute a challenge to the experienced spatial unity of self and body under normal conditions, that is the feeling that there is a "real me" that resides in my body and is both the subject and agent of my experiences (Blackmore, 2013; Zahavi, 2005). Probably for this reason, OBEs have attracted the attention of philosophers (Metzinger, 2004, 2005), psychologists (Blackmore, 1992; Irwin, 1985; Palmer, 1978), and neurologists (Blanke et al., 2004; Devinsky et al., 1989; Grüsser and Landis, 1991; Brugger et al., 1997) that have conceptualized OBEs as experiences due to deviant bodily self-consciousness arising from abnormal brain processes that code for the feeling of embodiment under normal conditions.

Incidence

How common are OBEs in the general population? This question is still difficult to answer as the relevant studies vary in several respects: (i) the different investigators have asked quite different questions about the presence of an OBE and (ii) have asked the questions either by mail, over the phone, or by interviewing subjects personally. Depending on the questions asked, how they are asked, and how an OBE is defined, the results are very likely to differ. In addition, (iii) most studies have been carried out in younger populations, mostly college students, mostly in Anglo-Saxon psychology departments. Accordingly, it is not surprising that questionnaire studies have estimated the OBE incidence differently (8–34%; reviewed in Blackmore, 1992). Also the two key elements (autoscopy and distanced visuo-spatial perspective) as used in neurobiologically motivated studies (see below) were not necessary OBE elements in most of these studies. We thus agree with Blackmore (1992) that incidences above 10% are very likely overestimates and suggest that ~5% of the general population have experienced an OBE. Finally, OBEs seem to occur across many cultures in the world, although to date only one study has investigated this interesting issue (Sheils, 1978).

Phenomenology

OBEs have to be distinguished from two other phenomena that also involve autoscopy: autoscopic hallucinations and heautoscopy. Whereas there is no disembodiment in autoscopic hallucinations and always disembodiment in OBEs, many subjects with heautoscopy generally do not report clear disembodiment,

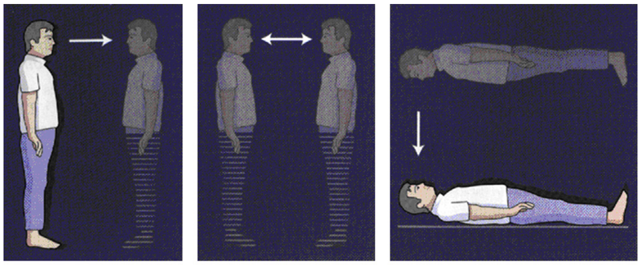

FIGURE 20.1 Illustration of three types of autoscopic phenomena (from Blanke and Mohr (2005)). In this figure the phenomenology of (A) autoscopic hallucination (AH), (B) heautoscopy (HAS), and (C) out-of-body experience (OBE) is represented schematically. The experienced position and posture of the physical body for each autoscopic phenomenon is indicated by full lines and the experienced position and posture of the disembodied body (OBE) or autoscopic body (AH, HAS) in blurred lines. The finding that AH and HAS were mainly reported from a sitting/standing position and OBE in a supine position is integrated into the figure. The experienced visuo-spatial perspective during the autoscopic phenomenon is indicated by the arrow pointing away from the location in space from which the patient has the impression to see (AH: from the physical body; OBE: from a disembodied body or location; HAS: alternating or simultaneously from either the fashion between physical and the autoscopic body). *Source: Modified from Blanke et al. (2004), with permission from Oxford University Press.*

but are not able to localize their self unambiguously (self-location may alternate between an embodied location and an extracorporeal one, or they might feel "localized" at both positions at the same time). Accordingly, the visuo-spatial perspective is body-centered in autoscopic hallucinations, extracorporeal in the OBE, and at different extracorporeal and corporeal positions in heautoscopy, with the impression of seeing one's own body (autoscopy) present in all three forms of autoscopic phenomena (Figure 20.1, for further details see Brugger, 2002; Blanke et al., 2004; Brugger et al., 1997; Blanke and Mohr, 2005; Blanke and Arzy, 2005).

OBEs have been the province of esoteric circles for much of their history. From this literature one may nevertheless find abundant phenomenological details and varieties of OBEs (e.g., Muldoon and Carrington, 1969; Yram, 1972; Monroe, 1977; for review see Blackmore, 1992). In addition, subjects with repeated OBEs (so-called "astral travelers") have not just given detailed accounts of their OBEs, but also proposed several procedures to induce OBEs that might be approached more systematically by researchers. These authors also reported about the phenomenological characteristics of the disembodied body, its location with respect to the physical body, the appearance of the autoscopic body, and the vestibular and bodily sensations associated with the experience (see Lippman, 1953). Yet, only a small minority of subjects with OBEs experience more than one or two in a lifetime. Most commonly, OBEs are therefore difficult to study because they generally are of short duration, happen only once or twice in a lifetime (Green, 1968; Blackmore, 1992) and occur under a wide variety of circumstances that we will review next.

Precipitating Factors

Several precipitating factors of OBEs have been identified. We review findings from neurology, psychiatry, drugs, and general anesthesia. OBEs will also be discussed in the context of NDEs (see "Out-of-Body Experiences" subsection).

Neurology

Only few neurological cases with OBEs have been reported in the last 50 years (Lippman, 1953, cases 1 and 2; Hécaen and Green, 1957, case 3; Daly, 1958, case 5; Lunn, 1970, case 1). Further more recent cases have been reported (Devinsky et al., 1989, cases 1, 2, 3, 6, 10; Maillard et al., 2004, case 1; Blanke et al., 2004, cases 1, 2a, 3) (see also Greyson et al., 2014). OBEs have been observed predominantly in patients with epilepsy, but also in patients with migraine (Green, 1968; Lippman, 1953); see also Jürgens et al. (2014). In his seminal study, Orin Devinsky et al. (1989) described many neurological OBE patients and reported patients whose OBEs were associated with non-lesional epilepsy (cases 6 and 10), with epilepsy due to an arteriovenous malformation (cases 2 and 3), or associated to posttraumatic brain damage (case 1). In another study (Blanke et al., 2004), OBEs were due to a dysembryoplastic tumor (cases 1 and 2a) and in one patient induced by focal electrical stimulation (case 3). Epileptic OBEs were also reported in a patient with focal cortical dysplasia (Maillard et al., 2004, case 1; see also Greyson et al., 2014; Ionta et al., 2011).

Whereas many authors (e.g., Devinsky et al., 1989) observed the frequent association of vestibular sensations and OBEs, Grüsser and Landis (1991) proposed that a paroxysmal vestibular dysfunction might be an important mechanism for the generation of OBEs. In another study (Blanke et al., 2004), the importance of vestibular dysfunction was underlined by their presence in all patients with OBEs and by the fact that vestibular sensations were evoked in a patient at the same cortical site where higher currents induced an OBE (Blanke et al., 2002). In more detail, it has been suggested that OBEs are associated with specific vestibular sensations, namely graviceptive, otholithic, or vestibular sensations (Blanke et al., 2004; Lopez et al., 2008). Otholithic sensations are characterized by a variety of sensations including feelings of elevation and floating, as well as a 180° inversions of one's body and visuo-spatial perspective in extrapersonal space. They may be associated with brain damage (Smith, 1960;

Brandt, 1999), but also occur in healthy subjects during orbital and parabolic flight during space missions or the microgravity phase of parabolic flights (Lackner, 1992; Mittelstaedt and Glasauer, 1993). Interestingly, responses to microgravity may either be experienced as an inversion of the subject's body and visuo-spatial perspective in extrapersonal space (inversion illusion) or as an inversion of the entire extrapersonal visual space that seems inverted by 180° to the stable observer (room-tilt illusion). Based on these functional similarities it was suggested that an otholithic dysfunction might not only be an important causal factor for room-tilt illusion and inversion illusion, but also for OBE (for further details see Blanke et al., 2004; Lackner, 1992; Blanke, 2012).

In addition to vestibular disturbances, it has been reported that OBE patients may also experience paroxysmal visual body-part illusions such as phantom limbs, supernumerary phantom limbs, and illusory limb transformations either during the OBE or during other periods related to epilepsy or migraine (Blanke et al., 2002, 2004; Devinsky et al., 1989; Lunn, 1970; Hécaen and de Ajuriaguerra, 1952). A patient was reported in whom OBEs and visual body-part illusions were induced by electrical stimulation at the right temporo-parietal junction (TPJ) (Blanke et al., 2002). In this patient an OBE was induced repetitively by electrical stimulation whenever the patient looked straight ahead (without fixation of any specific object). If she fixated her arms or legs that were stretched out, she had the impression that the inspected body part was transformed leading to the illusory, but very realistic, visual perception of limb shortening and illusory limb movement if the limbs were bent at the elbow or knee. Finally, with closed eyes the patient did have neither an OBE nor a visual body-part illusion, but perceived her upper body as moving towards her legs (Blanke et al., 2002). These data suggest that visual illusions of body parts and visual illusions of the entire body such as autoscopic phenomena might depend on similar neural structures as argued by previous authors (Brugger et al., 1997; Hécaen and de Ajuriaguerra, 1952). These data (Blanke et al., 2002) also show that visual body-part illusions and OBEs are influenced differently by the behavioral state of the subject.

Another functional link between OBE and disturbed own body perception is suggested by the fact that OBEs and autoscopic hallucinations (and heautoscopy) depend differently on the patient's position prior to the experience. This suggests that proprioceptive and tactile mechanisms influence both phenomena differently. Thus, during neurological OBEs patients are in supine position (Blanke et al., 2004; Blanke and Mohr, 2005) as was found by Green (1968) in 75% of OBEs in healthy subjects. Interestingly, most techniques that are used to deliberately induce OBEs recommend a supine and relaxed position (Blackmore, 1992; Irwin, 1985). This contrasts with the observation that subjects with autoscopic hallucination or heautoscopy are either standing or sitting at the time of their experience (Blanke et al., 2004; Blanke and Mohr, 2005; Dening and Berrios, 1994). It thus seems that OBEs depend on the subject's position prior or during the experience and that these differential proprioceptive, vestibular, and tactile mechanisms differentiate them from other types of autoscopic phenomena (see "Summary" section). The observation of OBEs during general anesthesia and sleep (see "General Anesthesia" section and Bünning and Blanke, 2005) also corroborates the notion that OBEs are facilitated by the sensory signals predominating in supine body position. Moreover, rapid bodily position changes such as brutal accelerations and decelerations have been associated with OBEs. This has long been reported by mountain climbers who unexpectedly fell (Heim, 1892; Ravenhill, 1913; Brugger et al., 1999; Firth and Bolay, 2004), as well as in car accidents (Devinsky et al., 1989; Muldoon and Carrington, 1969) and in the so-called "break-off phenomenon" experienced by airplane pilots (Benson, 1999). In this last case, a pilot might initially fail to sense correctly the position, motion or tilt of the aircraft as well as his own body position with respect to the surface of the earth and the gravitational "earth-vertical." These feelings can lead to several experiences grouped under the term "break-off phenomenon" that is characterized by feelings of physical separation from the earth, lightness, and an altered sense of the pilot's own orientation with respect to the ground and the aircraft (Benson, 1999; Clark and Graybiel, 1957; Sours, 1965). Some pilots have even described a feeling of detachment, isolation, and remoteness from their immediate surroundings which they sometimes describe as an OBE with disembodiment, elevated visuo-spatial perspective, and autoscopy (Benson, 1999; Tormes and Guedry, 1974). At the extreme, pilots feel being all of a sudden *outside* the aircraft watching themselves while flying, and being "broken off from reality." These OBEs are most often experienced by jet aviators flying alone, especially at high altitudes (above 10,000 m), although helicopter pilots can experience this phenomenon at altitudes of only 1500−3000 m (Benson, 1999; Tormes and Guedry, 1974). These OBEs seem facilitated by mental absorption (the pilot is unoccupied with flight details) and by the length and visual monotony of the mission (Benson, 1999). Monotony and absorption coupled with physical exhaustion might also be sufficient to trigger OBEs, as reported by long-distance runners (Morgan, 2002).

With respect to the underlying neuroanatomy, only few neurological OBE patients with circumscribed

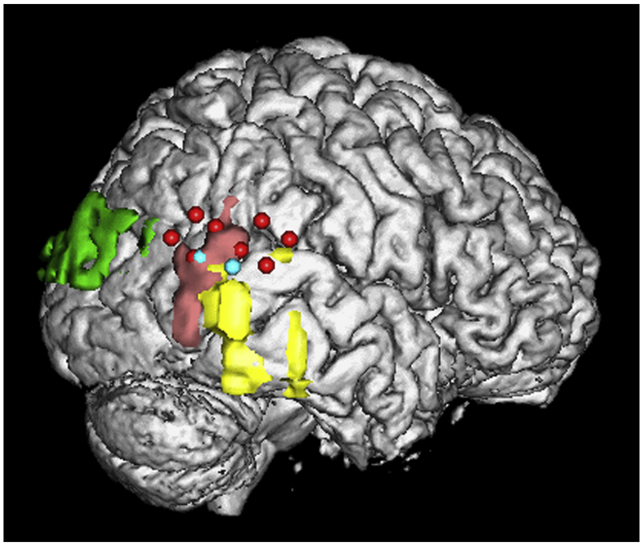

FIGURE 20.2 Lesion analysis of patients with documented brain anomalies and OBE. Mean lesion overlap analysis of five neurological patients with OBE in whom a lesion could be defined (Patients 1, 2, 3, 5, and 6 from Blanke et al. (2004)). The MRI of all patients was transformed into Talairach space and projected on the MRI of one patient. Each color represents a different OBE patient. Mean overlap analysis centered on the TPJ. For details, see Blanke et al. (2004), Blanke and Arzy (2005). *Source: Modified from Blanke et al. (2004), reproduced with permission from Oxford University Press.*

brain damage have been described. In some patients with OBEs, the seizure focus was estimated only by EEG recordings and localized to the temporal lobe or posterior temporal region (standard magnetic resonance imaging (MRI) or computer tomography was normal in most patients) (Devinsky et al., 1989). Yet, in one patient the lesion was found in the temporal lobe and in another patient in frontal and temporal lobe (Devinsky et al., 1989). Others (Lunn, 1970) described an OBE patient with posttraumatic brain damage in the parietal lobe, as well as an OBE patient with damage to the temporal lobe (Daly, 1958). More recent MRI-based analysis revealed a predominant involvement of the right TPJ in patients with OBEs (Blanke et al., 2004; Blanke and Mohr, 2005; Maillard et al., 2004; see Ionta et al., 2011 for more recent analysis). It has also been shown that electrical stimulation of the TPJ leads to OBEs, providing additional causal evidence for the importance of this region in the generation of OBEs (Blanke and Mohr, 2005) (Figure 20.2).

Psychiatry

While reports of autoscopic hallucinations and heautoscopy are not rare in patients suffering from schizophrenia, depression, and personality disorders (Blanke et al., 2004; Devinsky et al., 1989; Brugger et al., 1997; Hécaen and de Ajuriaguerra, 1952; Menninger-Lerchenthal, 1946; Lhermitte, 1998); others (Bünning and Blanke, 2005) found only two cases of OBE in psychiatric patients. One had severe depression (Hécaen and Green, 1957) and the other patient was undiagnosed (Zutt, 1953). Two questionnaire surveys have investigated OBEs in schizophrenia (Blackmore, 1986; Röhricht and Priebe, 1997) and found a similar incidence and phenomenology as in healthy subjects. A study in psychiatric patients suffering from posttraumatic stress disorder found a fourfold increase in prevalence as compared to healthy subjects (Reynolds and Brewin, 1999). Moreover, the personality measure of schizotypy is positively correlated with OBEs in healthy subjects and has also been shown to relate behaviorally and neurally (at the TPJ) to OBEs (Mohr et al., 2006; Arzy et al., 2007). As this trait reflects a continuum between healthy subjects and schizophrenic patients, these data suggest that OBEs are very likely more frequent in schizophrenic patients than currently thought. In addition, other personality traits such as individuals' somatoform (Murray and Fox, 2005a,b) but not general dissociative (Arzy et al., 2007) tendencies, body dissatisfaction (Murray and Fox, 2005a), or dissociative alterations in one's body image during a mirror-gazing task (Terhune, 2009) have also been linked to OBEs. Finally, in a questionnaire-based investigation, healthy individuals who experienced OBEs reported significantly more perceptual anomalies (e.g., body-distortion) and the tendency to be more hallucinatory-prone relative to individuals with no OBE (Braithwaite et al., 2011).

Drugs

The administration of different pharmacological substances has presumably been used since immemorial times in ritual practices to induce abnormal experiences including OBEs (Sheils, 1978). These include marijuana, opium, heroin, mescaline, ketamine, and lysergic acid diethylamide (LSD) (Blackmore, 1992; Grüsser and Landis, 1991; Lhermitte, 1998; Tart, 1971; Aizenberg and Modai, 1985). Concerning marijuana, Tart (1971) found that OBEs occurred in 44% of a sample of 150 college students who used this drug (see also Bünning and Blanke, 2005), that is, a much higher frequency than in the general population. However, a majority of the subjects with OBEs in this study frequently used other drugs such as LSD. It is thus not clear whether the higher frequency of OBEs is due to marijuana consumption or the consumption of other drugs. Experiences related to OBEs such as a feeling of floating or of being dissociated from one's body, have also been induced under controlled conditions by marijuana administration compared with placebo administration (Siegel, 1977), although similar data with respect to OBEs or other autoscopic phenomena are lacking. Moreover, the intake of therapeutic marijuana was shown to induce

OBE in a patient with tetraplegia and severe somatosensory loss due to large lesions in the cervical spinal cord (Overney et al., 2009). Recently, an online survey investigated the strength of the association of OBEs with ketamine use relative to other common substances (Wilkins et al., 2011). The results suggest that both lifetime frequency of ketamine use and OBEs during ketamine intoxication were more strongly related to the frequency of OBEs than other drugs, and that the apparent effects of other drugs could largely be explained by associated ketamine use. In another survey (Corazza and Schifano, 2010), the large majority (90%) of NDEs with a strong sense of disembodiment were also reported to occur during first instances of ketamine use. These authors proposed that by impacting NMDA receptors (Jansen, 1997) ketamine may affect the availability and integration of multisensory signals, including those mediated by the temporo-parietal junction (TPJ) (see below).

General Anesthesia

It has long been known that conscious perceptions may occur under general anesthesia: "Awareness during anesthesia is as old as the specialty itself" (Spitellie et al., 2002). Insufficient levels of anesthesia combined with the application of muscle relaxants seem to be the main cause of this preserved awareness. Another pathophysiological factor might be related to hemodynamic cerebral deficits, most notably in anesthesized patients undergoing cardiac and posttraumatic surgery (Sandin, 2003; Sandin et al., 2000). OBEs in association with general anesthesia have been described in retrospective case collections (Muldoon and Carrington, 1969; Crookall, 1964), but also in more recent patient studies (Ranta et al., 1998, patient 3, Cobcroft and Forsdick, 1993, 4 of 187 patients). Such a patient reports: "I had the strangest [...] sensation of coming out of my self; of being up at the ceiling looking down on the proceedings [of the operation]. After the initial realization that I couldn't communicate at all, came the feeling of acceptance... of being aware of having one hell of an experience" (Cobcroft and Forsdick, 1993). Several patients reported that they "left their body during the operation at some point" (Osterman et al., 2001). Although OBEs are quite rare during general anesthesia, this is probably linked to the relative infrequency of visual awareness during general anesthesia, and the much higher frequency of auditory perceptions (89%), sensations of paralysis (85%), motor illusions and bodily transformations (30–40%), and pain (39%). Visual perceptions were reported in only 27% of patients (Moerman et al., 1993; see also Cobcroft and Forsdick, 1993). Yet, among patients with visual perceptions, many reported disembodiment and seeing the surgeon and other people or surroundings of the operating theater during the actual operation. Thus, if analyzed only with respect to the presence of visual awareness and experiences in the context of general anesthesia, OBEs and OB-like experiences are not so rare. This is of special interest because paralysis, complex own body perceptions, and supine position are not only frequent during general anesthesia with preserved awareness, but also frequently reported by subjects with OBEs of spontaneous or neurological origin (Blackmore, 1992; Blanke et al., 2004; Blanke and Mohr, 2005; Irwin, 1999). Concerning hemodynamic cerebral deficits that have been shown to be associated with an increased incidence of awareness during anesthesia (Bünning and Blanke, 2005), it is interesting to note that they may lead to rather selective and initially focal decreases in cerebral blood flow and as a consequence induce transient or manifest brain infarctions that frequently include the TPJ (Ringelstein and Zunker, 1998) suggesting that OBEs under general anesthesia might be related to the functional and anatomical pathomechanisms as described in neurological patients with epilepsy, migraine, and cerebrovascular disease.

Experimental Induction of OBE States

Besides pathological conditions and drug studies, researchers can now simulate out-of-body illusions in healthy volunteers using video, virtual reality, or robotic devices (Ionta et al., 2011; Ehrsson, 2007; Lenggenhager et al., 2007; for a review see Blanke, 2012). In these studies, full-body (or "out-of-body") illusions are generally induced by the application of multisensory conflicts between a visual stimulus and a tactile, vestibular, or cardiac one. For instance, a tactile stroking stimulus is repeatedly applied to the back (Lenggenhager et al., 2007) or chest (Ehrsson, 2007) of a participant who is filmed, and simultaneously sees a human body being stroked at corresponding body parts. As in classical OBEs, participants view an image of their own body (the "virtual body") from an "outside," third-person perspective while feeling tactile stimulations on their skin. Under such conditions, a multisensory conflict arises, as what is seen (i.e., one's avatar being stroked) does not match what is felt (one's back being stroked). The illusion vanishes when a temporal delay is added between the visual and tactile stimulus (i.e., asynchronous visuo-tactile condition). Out-of-body and full-body illusions are usually associated with changes in self-location and self-identification. Indeed, as compared to asynchronous visuo-tactile conditions, participants in synchronous visuo-tactile conditions self-identify more strongly with the seen virtual body, judge their self-location as closer to it, and feel that the tactile stimulus emanates from it. These subjective changes support the idea that self-identification and self-location are based on the integration of multisensory signals. In addition, experimental alterations of bodily self-consciousness are also associated with changes at the physiological level (i.e., skin conductance response to a threat directed towards the virtual body (Ehrsson, 2007; Petkova and Ehrsson, 2008); body temperature (Salomon et al., 2013); nociceptive thresholds (Hänsell et al., 2011)). This suggests that changes in bodily self-consciousness induced by exteroceptive multisensory conflicts (e.g., visuo-tactile) interact with the interoceptive homeostatic systems. Consistent with this idea, the level of interoceptive sensitivity (e.g., as measured in a heartbeat counting task) can be used as a predictor of changes in self-other boundaries in response to multisensory stimulation (Tsakiris, 2010; Tajadura-Jiménez and Tsakiris, 2014).

To what extent are interoceptive bodily signals themselves relevant for bodily self-consciousness, and how do they interact with external bodily signals? While the large majority of cited studies manipulated exteroceptive signals (i.e., vision and touch) in order to manipulate bodily self-consciousness, behavioral, imaging, and neurological results also suggest that the brain's representations of internal bodily states (Critchley et al., 2004) are primordial for the self (Damasio and Dolan, 1999; Craig, 2009). Accordingly, modulations of bodily consciousness due to conflicts between an interoceptive signal (e.g., the heartbeat) and an exteroceptive one (e.g., a visual stimulus) have been documented. Aspell and colleagues (2013) showed that a colored silhouette surrounding the virtual body and flashing in synchrony with respect to the participant's heartbeats also induced changes in self-identification and self-location. Importantly, changes in bodily self-consciousness under these conditions were of similar magnitude to those that stemmed from purely exteroceptive conflicts (i.e., visuo-tactile; for related work with a rubber hand illusion, see Suzuki et al., 2013). These findings are compatible with proposals that both exteroceptive and interoceptive signals are important for bodily self-consciousness (see also Seth et al., 2011). As integrated interoceptive and exteroceptive signals show to be potent modulators of bodily self-consciousness, it may be argued that central processing of signals from the inside and the outside of the human body form an integrated cortical system for bodily self-consciousness, and thus might be important factors in OBEs.

Brain regions involved in the processing of interoceptive signals like the insula (Critchley et al., 2004) are likely to be crucial components of this system. A few neuroimaging studies on bodily self-consciousness have linked self-identification and self-location to several brain regions using different paradigms and techniques. The role of insula is supported by functional connectivity analysis during the full-body illusion (Petkova et al., 2011) and neurological data in patients suffering from heautoscopy (Brugger, 2002; Heydrich and Blanke, 2013). Moreover, changes in self-identification were shown to be associated with activity in bilateral ventral premotor cortex, left posterior parietal cortex, and the left putamen (Petkova et al., 2011). In another study, Ionta and colleagues (2014) found that self-identification with a virtual body was associated with activation in the right middle-inferior temporal cortex (partially overlapping with the extrastriate body area), a region that is, like the premotor cortex, involved in the multisensory processing of human bodies (Downing et al., 2001; Grossman and Blake, 2002; Astafiev et al., 2004). Importantly, activity in bilateral temporo-parietal cortex (in proximity with the lesion overlap zone associated with OBEs of neurological origin by Ionta et al., 2011) differed between synchronous and asynchronous visuo-tactile conditions, and depended on the experienced direction of the first-person perspective (i.e., seeing a virtual body from an elevated or lowered perspective while laying down in a supine position). More recent experimental data suggested that these subjective changes in the first-person perspective are associated with inter-individual differences in visuo-vestibular integration (Pfeiffer et al., 2013). The influence of vestibular signals on first-person perspective and bodily self-consciousness is notably supported by the proximity of the vestibular cortex to TPJ (Lopez and Blanke, 2011), and the frequent vestibular disturbances that occur during OBEs of neurogical origin. Accordingly, we argue that changes in the experienced direction of the first-person perspective are due to abnormal signal integration of vestibular and visual cues (see Blanke, 2012 for review). Taken together, the reviewed brain imaging studies implicate brain areas that integrate multisensory bodily signals and thus provide further evidence for the link between multisensory body representations, bodily self-consciousness, and OBEs, in particular in bilateral temporo-parietal cortex.

Summary

The reviewed data point to an important involvement of bilateral, but in particular the right TPJ in OBEs and related processing with respect to bodily self-consciousness. The observation that electrical stimulation of this area may induce OBEs and other altered own body perceptions further suggests that during OBEs the integration of proprioceptive, tactile, visual, and vestibular information of one's body is altered due to discrepant central own body representations. Blanke and colleagues have suggested (Blanke et al., 2004; Blanke and Mohr, 2005) that autoscopic phenomena (including OBEs) result from a failure to integrate multisensory bodily information and proposed that they result from a disintegration in bodily or personal space (due to conflicting tactile, proprioceptive, kinesthetic, and visual signals) and a second disintegration between personal and extrapersonal space (due to conflicting visual and vestibular signals caused by a vestibular otolithic dysfunction). While disintegration in personal space is present in all three forms of autoscopic phenomena (see also Heydrich and Blanke, 2013), differences between the different forms of autoscopic phenomena are mainly due to differences in strength and type of the vestibular dysfunction. Following this model, OBEs were associated with a strong otolithic vestibular disturbance, whereas heautoscopy was associated with a moderate and more variable vestibular disturbance (and the association with interoceptive signals (Heydrich and Blanke, 2013)), and autoscopic hallucinations without any vestibular disturbance. Neuroimaging studies have revealed the important role of the TPJ in vestibular processing, multisensory integration as well as the perception of human bodies or body parts and the self (see Bünning and Blanke, 2005; Blanke and Arzy, 2005). Multisensory stimulation and involvement of the temporo-parietal cortex in OBEs and related out-of-body illusions has recently also been confirmed in healthy subjects (Ionta et al., 2011) and previously in a study using high-density electroencephalography and transcranial magnetic stimulation (Arzy et al., 2007). Taken together, these results (Blanke and Arzy, 2005, see also Arzy et al., 2006, 2007) suggest that the TPJ and an associated larger network are crucial structures for OBEs and for the conscious experience of the self-characterized by spatial unity of self and body.

NEAR-DEATH EXPERIENCES

Definition

In different life-threatening situations, people can sometimes experience vivid illusions and hallucinations as well as strong mystical and emotional feelings often grouped under the term near-death experience (NDE). These medical situations seem to involve cardiac arrest, perioperative or postpartum complications, septic or anaphylactic shock, electrocution, coma resulting from traumatic brain damage, intracerebral hemorrhage or cerebral infarction, hypoglycemia, asphyxia, and apnea. To this date, systematic studies on the incidence of NDEs in verified medical conditions only exist for cardiac arrest patients (Van Lommel et al., 2001; Parnia et al., 2001; Schwaninger et al., 2002; Greyson, 2003; Parnia et al., 2014). Other situations that are merely *experienced* as life-threatening have also been reported to be associated with NDEs, although they often are not objectively life-threatening (mild or not life endangering diseases, depression, minor accidents, falls, and other circumstances (Van Lommel et al., 2001)).

Several definitions have been attempted for NDEs. Moody (2001) coined the term NDE defining it as "any conscious perceptual experience which takes place during... an event in which a person could very easily die or be killed [...] but nonetheless survives" (Moody, 1977, p. 124). Irwin (1999) defined NDEs as "a transcendental experience precipitated by a confrontation with death" and Nelson et al. (2006) state that "NDEs are responses to life-threatening crisis characterized by a combination of dissociation from the physical body, euphoria, and transcendental or mystical elements." Greyson (2005) proposed that NDEs are "profound subjective experiences with transcendental or mystical elements, in which persons close to death may believe they have left their physical bodies and transcended the boundaries of the ego and the confines of space and time." Many more such broad definitions of the NDE have been given (Smith, 1991; Greyson, 1999) rendering their scientific study difficult. They seem to include a large variety of phenomena and not all researchers may agree that the investigated phenomenon (or assembly of phenomena) of a given study, may actually concern NDEs or "typical" NDEs. Below, we have reviewed the most frequent and characteristic perceptual elements of NDEs (see "Phenomenology" section). To complicate matters NDEs (as OBEs) are difficult to study as their occurrence is unpredictable and they are generally not reported at their moment of occurrence, but days, months, or even only years later.

Incidence

Early studies about the incidence of NDEs among survivors of cardiac arrest, traumatic accidents, suicide attempts, and other life-threatening situations estimated an incidence of 48% (Ring, 1982) or 42% (Sabom, 1982). Greyson (1998) suggested that this rate is probably too high as these studies were retrospective, often carried out many years after the NDE occurred, were using self-selected populations, and lacked appropriate control populations. He rather estimated the incidence of NDEs between 9% and 18%. More recent and better controlled prospective studies focused on cardiac arrest patients and confirmed lower estimations, with values ranging between 6% and 12%. These found an incidence of 6.3% (Parnia et al., 2001), 10% (Greyson, 2003), and 12% (Van Lommel et al., 2001). Yet, as indicated in the section on OBEs, in the absence of a clear and widely accepted definition of NDEs, it will remain difficult to define their exact incidence (Smith, 1991; Greyson, 1998, 1999, 2005). In order to avoid this problem most recent

TABLE 20.1 Phenomenological Features of NDEs According to Several Authors

Moody (1975)	Ring (1982)	Greyson (1983)
Identified 15 common elements in NDEs based on a sample of 150 reports. No statistics were provided. **1.** Ineffability **2.** Hearing oneself pronounced dead **3.** Feelings of peace and quiet **4.** Hearing unusual noises **5.** Seeing a dark tunnel **6.** Being "out of the body" **7.** Meeting "spiritual beings" **8.** Experiencing a bright light as a "being of light" **9.** Panoramic life review **10.** Experiencing a realm in which all knowledge exists **11.** Experiencing cities of light **12.** Experiencing a realm of bewildered spirits **13.** Experiencing a "supernatural rescue" **14.** Sensing a boarder or limit **15.** Coming back "into the body."	Identified five stages of a "core experience," based on structured interviews and a measurement scale (WCEI: weighted core experience index) administered to 102 individuals who have been near death, 48% of whom reported a NDE. These stages tended to appear in sequence, with the earlier ones being more frequent and the latter ones indicating the "depth" of the experience. **1.** Peace and well-being, reported by 60% **2.** Separation from the physical body (OBE), reported by 37% (half of whom had an autoscopic OBE) **3.** Entering a tunnel-like region of darkness, reported by 25% **4.** Seeing a brilliant light, reported by 16% **5.** Through the light, entering another realm, reported in 10%.	Devised a typology of NDEs based on his development of the 16-item NDE scale. On the basis of cluster analysis, he arrived at one's four categories of NDEs each comprising four features. **1.** Cognitive features **a.** time distortion **b.** thought acceleration **c.** life review **d.** revelation **2.** Affective **a.** peace **b.** joy **c.** cosmic unity **d.** encounter with light **3.** Paranormal **a.** vivid sensory events **b.** apparent extrasensory perception **c.** precognitive visions **d.** OBEs **4.** Transcendental **a.** sense of an "otherworldy" environment **b.** sense of a mystical entity **c.** sense of deceased/religious spirits **d.** sense of border/"point of no return."
Sabom (1982)	**Noyes and Slymen (1984)**	**Lundahl (1992)**
Proposed from his investigation of 48 subjects with NDE three main types of experiences. **1.** "Autoscopic" (i.e., the NDE is essentially an OBE) **2.** Transcendental (apparently entering another "dimension" through a tunnel and meeting a personified light) **3.** Combined (involving an OBE and transcendental features).	Conducted a factor analysis of questionnaire responses from 189 victims of life-threatening accidents, and found the following three factors of subjective effects that accounted for 41% of the variance. **1.** Depersonalization (loss of emotion, separation from the body and feelings of strangeness or unreality) **2.** Hyperalertness (vivid and rapid thoughts, sharper vision and hearing) **3.** Mystical consciousness (feeling of great understanding, vivid images, life review).	Summarized the NDE literature and extracted what he saw as the ten main stages. **1.** Peace **2.** Bodily separation **3.** Sense of being dead **4.** Entering the darkness **5.** Seeing the light **6.** Entering another world **7.** Meeting others **8.** Life review **9.** Deciding to or being told to return to life **10.** Returning to the body.

studies have used a score above a certain value on a frequently used scale (Greyson, 1983, see below).

Early studies failed to find demographic correlates of the NDE. Neither age, nor gender, race, occupational status, marital status, religiosity seemed to predict the probability of reporting an NDE (Ring, 1982; Sabom, 1982). More recently, two studies (Van Lommel et al., 2001; Greyson, 2003) found that young age is associated with a higher probability of NDEs in cardiac arrest patients, although this finding might be confounded by increased medical recovery rates in younger cardiac arrest patients. Another finding is that women tend to have more intense NDEs than men (Ring, 1982; Van Lommel et al., 2001) an observation that might partly be related to suggestions (Moody, 2001) that women might be less afraid to report NDEs or the fact that women have been found to score generally higher on anomalous-perception questionnaires than male subjects (Mohr et al., 2006). It is possible that having had a NDE facilitates the re-occurrence of such experiences, as 10% of subjects reported multiple NDEs (Van Lommel et al., 2001). NDEs have been described in many different cultures and times. Although some consistency can be found in cross-cultural reports, the specific phenomenology (i.e., the structure and the contents of the experience) may nevertheless vary (Osis and Harraldsson, 1977; Zaleski, 1988; Walker and Serdahely, 1990; Groth-Marnat, 1994).

Phenomenology

Moody (1977, 2001) initially listed 15 key features in NDEs (see Table 20.1). Yet, not one single NDE in his sample included all 15 NDE features. Moreover, none of these 15 NDE features was present in all reported NDEs, and no invariable temporal sequence of features could be established. Due to these difficulties, standardized questionnaires have subsequently been developed to identify and measure more precisely the occurrence of NDEs and their intensity (or depth). Ring (1982) developed the Weighted Core Experience Index on the basis of structured interviews of 102 persons who reported a NDE. The scale is based on ten features that he gathered from the literature as well as interviews with people with NDEs. His ten features were: the subjective feeling of being dead, feelings of peace, bodily separation, entering a dark region, encountering a presence or hearing a voice, life review, seeing or being enveloped in light, seeing beautiful colors, entering into the light, and encountering visible spirits. According to the presence or absence of each of these features, the score ranges between 0 and 29. This scale has been criticized because it is largely based on arbitrary selected and weighted features, and seemed to contain several uncommon features of NDEs as estimated by other authors. Ring (1982) also elaborated a sequence of five NDE-stages, the presence of which he considered to be representative of the "core NDE" (see Table 20.1). To address the aforementioned limitations, Greyson (1983) developed a NDE scale that has been used by many recent investigators. He began by selecting 80 features from the existing literature on NDEs and subsequently reduced these to 33 features. He further arrived at a final 16-item scale with a maximum score of 32. This questionnaire has been shown to have several advantages as compared to other questionnaires, especially good test-retest reliability (even for a follow-up at 20 years; Greyson, 2007) and item score consistency (Lange et al., 2004). In the original study (Greyson, 1983), four NDE components were defined—cognitive, affective, paranormal, and transcendental—which were later reduced to a classification of three main types of NDEs, according to the specific dominance of the phenomenological components: cognitive, affective, and transcendental types (Greyson, 1985) (see Table 20.1). In the following we describe the main phenomena that characterize NDEs.

Out-of-Body Experiences

OBEs are considered a key element of NDEs, although their frequency was found to vary greatly between the different studies. Ring (1982) found that 37% of subjects with a NDE experienced disembodiment ("being detached from their body") of whom about half also experienced autoscopy (no detailed data were reported on elevation or visuo-spatial perspective). Others (Greyson and Stevenson, 1980) found an incidence of 75% of disembodiment (without detailing the presence of autoscopy or elevated visuo-spatial perspective) or reported a "sense of bodily separation" in 99% (Sabom, 1982), whereas still others reported disembodiment in only 24% (Van Lommel et al., 2001). Disembodiment during NDEs has been reported to be accompanied by auditory and somatosensory sensations (Irwin, 1999). NDE subjects with OBEs characterized by disembodiment and elevated visuo-spatial perspective often report seeing the scene of the accident or operating room. A 26 year-old patient with pulmonary embolism reported: "I (the real me, the soul, the spirit, or whatever) drifted out of the body and hovered near the ceiling. I viewed the activity in the room from this vantage point. The hospital room was to my right and below me. It confused me that the doctors and nurses in the room were so concerned about the body they had lifted to the bed. I looked at my body and it meant nothing to me. I tried to tell them I was not in the body (p. 393)" (Greyson, 1993). We argue that future studies on OBEs during NDEs should characterize OBEs with respect to recently defined phenomenological characteristics and inquire systematically about the associated sensations as done in neurological patients (such as visual, auditory, bodily, or vestibular sensations) as well as the presence of disembodiment, autoscopy, elevated perspective permitting to distinguish between autoscopic hallucination, heautoscopy, and OBE. This will allow describing the phenomenology of OBEs during NDEs in more detail and allow relating these data to recent neurological and neurobiological observations on OBEs. Not much is known about whether OBEs that are associated with NDEs differ from OBEs without NDE elements or whether NDEs with or without OBEs differ. Alvarado found (Alvarado, 2001) that OBEs in subjects who believed themselves to be close to death were phenomenologically richer than for those who did not, with more feelings of passing through a tunnel, hearing unusual sounds, seeing spiritual entities, as well as seeing one's physical body and seeing lights (see also Gabbard et al., 1981). Of course, it might be the case that due to the presence of these features these subjects *believed* they had been close to death (no medical data were reported). Further links might exist between rare, the so-called supernaturalistic, OBEs (Irwin, 1985) and OBEs during NDEs. Accordingly, other authors have compared the phenomenology of NDEs in subjects being medically close to death with NDEs where subjects only *believed* to be close to death (as established from medical records) and found that the former group reported more often seeing lights and enhanced cognition than the latter group (Owens et al., 1990). There were no significant differences between both groups in seeing tunnels (see below), having OBEs and experiencing a life review (see below). However, a more recent study failed to find differences in the intensity and content of NDEs of varied etiologies occurring during life-threatening ("real NDEs") and non-life-threatening ("NDE-like") events (Charland-Verville et al., 2014). In another study, 76% of subjects with NDEs were reported to also experience an OBE (Nelson et al., 2007). Around 40% of these patients had their OBE only as part of the NDE episode, ~33% also had OBEs in other circumstances, and ~26% had an OBE only in other circumstances, i.e., not associated with the NDE. This last number was significantly higher than non-NDE-related OBEs in an aged-matched control group of healthy subjects (Nelson et al., 2007). Collectively, these data suggest that OBEs and NDEs may share important functional and brain mechanisms, but clearly point towards distinct mechanisms as well.

The Tunnel and the Light

Experiencing a passage through some darkness or a tunnel is experienced by ~25% of subjects with NDEs (Ring, 1982; Sabom, 1982; Van Lommel et al., 2001). This may be associated with the sensation of movement of one's own body such as forward vection, flying, or falling, at varying speeds. Some (Owens et al., 1990; Drab, 1981) suggest that the experience of a tunnel is associated with the presence of severe medical conditions (such as cardiac arrest, drowning, trauma, profuse blood loss), as opposed to mild injuries, fear, or fatigue. Here is one example: "After I had floated close to the ceiling for a short time, I was sucked into a tunnel.... It was black and dark around me, somewhat frightening, but this did not last long: at the end of the tunnel I saw a clear light towards which I traveled" (p. 211) (Woerlee, 2005). The tunnel experience or darkness may thus be associated with the experience of intense light. This was found to be the case in half of the subjects with NDEs (Drab, 1981), whereas others found that 30% (Ring, 1982; Sabom, 1982) or 23% (Van Lommel et al., 2001) reported seeing a light (but did not investigate how frequently this was associated with the experience of a tunnel). It is usually white or yellow, very bright, but not experienced as painful. The light seems to cover a larger area in the visual field when subjects experience vection (Drab, 1981).

The Life Review

The life review has been defined as the perception of "unusually vivid, almost instantaneous visual images of either the person's whole life or a few selected highlights of it" (Irwin, 1999, p. 204). Heim (1892) reports the following life review during a fall during mountaineering: "...I saw my whole past life take places in many images, as though on a stage at some distance from me. I saw myself as the chief character in the performance. Everything was transfigured as though by a heavenly light and everything was beautiful without grief, without anxiety, and without pain." Life reviews were found in 13–30% of subjects with NDEs (Ring, 1982; Van Lommel et al., 2001; Greyson, 1983; Greyson and Stevenson, 1980; Noyes and Kletti, 1976). In an analysis of 122 subjects with NDEs it was found that the number of distinct life memories may range from few images (one or two) to the impression of a rapid flow of countless images depicting their entire life (Stevenson and Cook, 1995). Some subjects reported that the life review unfolds with an infinite number of images, simultaneously ("all at once"). The life review is usually experienced very vividly, associated with bright colors and can occur as moving in chronological order or in the opposite order (i.e., ending or starting with childhood (Blackmore, 1993)). It can also purportedly involve elements of the future (Groth-Marnat, 1994). Two studies speculated that life reviews are especially frequent in drowning victims, as compared to other situations (Noyes and Kletti, 1976; Dlin, 1980). Conversely, it seems that suicide survivors (Rosen, 1975) and children (Morse et al., 1986; Serdahely, 1990) rarely report life reviews during NDEs.

Meeting of Spirits

People often report seeing or feeling different entities or people during NDEs. Here is an example from a man with cardiac disease: "...he experienced an apparent encounter with his deceased mother and brother-in-law, who communicated to him, without speaking, that he should return to his body" (Greyson, 2000, p. 315). The encounters are sometimes identified as supreme beings, pure energy, spiritual guides, angels, helpers, or familiar people, but also as demons or tormentors (Judson and Wiltshaw, 1983; Lundahl, 1992; Kelly, 2001). These encounters are reported frequently during NDEs (40% (Ring, 1982); 52% (Greyson, 2003): "sense of deceased/religious spirits," see Table 20.1). Sometimes subjects report to feel (rather than see) the presence of an unfamiliar person, a mystical, or a supreme entity (reported by 26% of NDE subjects (Greyson, 2003)). The seen or felt person may also be familiar, but is most often a deceased relative or friend. Ring (1982) and Kelly (2001) respectively found that 8% and 13% of seen or felt persons were dead relatives, whereas others ((Fenwick and Fenwick, 1997) 39%; (Van Lommel et al., 2001) 32%) found this more frequently. This feature was further analyzed by comparing 74 people with NDEs who reported to have perceived one or more deceased relatives with 200 people with NDE who did not (Kelly, 2001). It was found that deceased relatives are more frequently reported than deceased friends or children (in this study only 4% of people with NDEs reported seeing persons that were alive at the time of the NDE (Kelly, 2001)). Encounters with dead relatives have long been reported in the occult literature as "apparitions" and are supposed to be frequent in the so-called "deathbed visions" (Osis and Harraldsson, 1977; Barrett, 1926). Sometimes verbal or thought communication (often described as "telepathic") has been reported to take place between the subject and the encounters. Physical interactions such as touch or embraces are sometimes described as well (Greyson, 2000). Some of these features have also been reported in neurological patients with heautoscopy (Blanke and Mohr, 2005).

Positive and Negative Emotions

NDE reports often consist of feelings of peace and calm (and sometimes ecstasy), despite the experienced severity of the situation. Whereas Ring (1982) found that 60% of subjects with a NDE reported feelings of peace (56% in Van Lommel et al., 2001), others (Sabom, 1982) noted such feelings in all subjects with NDE. Analyzing feelings of peace and joy separately, the presence of peace was found in 85% and joy in 67% (Greyson, 2003). A related feature might be the loss of pain sensations as subjects with NDE often report to be relieved from the unbearable pain they were enduring minutes earlier. Heim (1892) reports his own experience when falling from a cliff: "There was no anxiety, no trace of despair, nor pain; but rather calm seriousness, profound acceptance, and a dominant mental quickness and sense of surety..." (see also Ernest Hemingway's account of his own painless NDE, despite suffering from multiple shrapnel wounds (Dieguez, 2010)). Many subjects also report feelings of absolute love, all encompassing acceptation, often by a supreme entity, which is associated with a radiant light. Nevertheless, NDEs may also be associated with negative emotions, with "hell"-like features, encounters with tormentors or frightfully devoid of any meaning (Greyson and Bush, 1992). The exact incidence of such negative NDEs is not known, but it is assumed to be rather low (Greyson, 2000).

Other Features

In this section we have listed other NDE features about which less is known concerning their phenomenology, frequency, and association with other features. These features are realness, mental clarity, sense of time, mystical elements, and the experience of border and return.

Realness and Mental Clarity

Although NDEs are often described as highly realistic sensations, we were not able to find detailed estimates. In the literature we found reports that NDEs are often experienced as "real" or "realer than real" (Potts, 2002). Some authors have argued that NDEs are qualitatively different from dreams or drug-induced hallucinations (e.g., Moody, 2001). As one subject wrote: "For many years, it was the most real thing that ever happened to me. Yes, far more real and vivid than any real-life incident. It was so real, detailed and so vivid and consistent...; in fact, so totally un-dream-like!" (Blackmore, 1993, p. 137). Thus, many subjects with NDEs believe them to be an *actual* disembodiment, meeting of spirits, seeing of lights, or of being in the afterworld rather than mere experiences thereof. These subjects are often reluctant to refer to NDEs in psychological or neurophysiological terms (Schwaninger et al., 2002). A recent study compared NDE memories to real and imagined memories, including non-NDE coma memories. It was found that NDE memories had richer content than all other types of memories, including better clarity and more self-referential and emotional information, suggesting that memories of NDEs are more akin to flashbulb memories and hallucinatory experiences than imagined events. These characteristics seem related to the content of the memory *per se*, rather than medical factors or actual closeness to death, and help understand why such experiences are often perceived as "super real," even more so than real recent events (Thonnard et al., 2013). Realness is sometimes also reported as mental clarity or cognitive enhancement. The report of clear experience, perception, and cognition was more frequent in subjects who suffered serious life-threatening conditions than those who only thought themselves in great biological danger (Owens et al., 1990). Others found that 44% of NDE subjects reported accelerated thought with their NDE (Greyson, 2000). Heim (1892) refers to this aspect during a mountain fall: "All my thoughts and ideas were coherent and very clear, and in no way susceptible, as are dreams, to obliteration...The relationship of events and their probable outcomes were viewed with objective clarity, no confusion entered at all."

Sense of Time

A distorted sense of time is a frequent feature of NDEs, but has not been described in detail in statistical and phenomenological terms. Already Heim (1892) reported that "time became greatly expanded" during his fall. More recent investigators (Greyson, 2000) found that 67% of NDE subjects reported an alteration of the sense of time, whereas this was much less frequent in a control group of subjects without NDEs (4%). Based on the reviewed phenomenology we suggest that the presence of a distorted sense of time, mental clarity, and life review might co-occur in subjects with NDEs.

Mystical and Transcendental Elements

A feeling of "oneness" with the universe or of "cosmic unity" was present in 52% of subjects with NDEs (Greyson, 2000). Other studies reported that 20% (Ring, 1982) or 54% (Sabom, 1982) of the questioned NDE subjects reported the "visit" of a supernaturalistic environment. This value is considerably smaller in people reporting OBEs (~1%; Irwin, 1985), but more frequent in subjects who report multiple OBEs. Descriptions here vary considerably, but most often seem to involve the experience of seeing pleasant sights like cities of light, green and flowered meadows, and vivid colors. Sometimes, images reminiscent of religious iconography are perceived (Irwin, 1987).

Border and Return

A symbolic or concretely perceived limit or border is sometimes reported by subjects with NDEs. Greyson (2000) found this in 41% and Van Lommel et al. (2001) in 8%. NDEs (and OBEs) are often reported to end abruptly without the experience of intentional control (Irwin, 1999). A patient, resuscitated by electrical defibrillation after an anterior myocardial infarction, reported: "It appeared to me…that I had a choice to re-enter my body and take the chances of them [the medical staff] bringing me around or I could just go ahead and die, if I wasn't already dead. I knew I was going to be perfectly safe, whether my body died or not. They thumped me a second time. I re-entered my body just like that (quoted in Rogo, 1986, p. 65)." The immediate aftermath is frequently the return of pain and the realization that one is alive (similar observations have also been reported in neurological patients with OBEs and related experiences such as heautoscopy; see below and Blanke et al., 2004, case 4).

Folk-Psychological Accounts and Psychological Aspects

Following psychoanalytic theory, several researchers consider NDEs as a defense mechanism unfolding in a hopeless, life-threatening situation. Noyes and Kletti (1976, 1977) were influential with their suggestion that the experience during a NDE may reflect a form of depersonalization, whereby the endangered subject "separates" from the body and the current events in order to be "separated" from the intolerable consequences of death and pain. Following Albert Heim's (1892) report of NDEs in fall survivors, Oskar Pfister suggested that "persons faced with potentially inescapable danger attempt to exclude this unpleasant reality from consciousness and "replace" it with pleasurable fantasies which protect them from being paralyzed by emotional shock" (Pfister, 1930 quoted in Grosso, 1983, p. 613). By this process, it was then argued that subjects "split" into an observing self and a body. The OBE component of many NDEs, in particular, has been seen as the prototypic experiential correlate of this detachment (Menz, 1984; Ehrenwald, 1974) (for critique see Gabbard and Twemlow, 1984; Irwin, 1993). Psychological authors suggested that NDEs are the consequence of a human tendency to deny death (Menz, 1984; Ehrenwald, 1974), the release of archetypical concepts of death (Grosso, 1983), or the (symbolic or literal) regression to the experience of coming to life (Grof and Halifax, 1978; Sagan, 1980; but see Blackmore, 1993). These approaches of NDEs suffer from the same methodological and scientific concerns as psychoanalytical propositions.

More quantitative approaches have proposed to analyze psychological variables of people with NDEs, as estimated by interviews and questionnaire surveys. However, in comparison to OBEs, no clear psychopathological features have yet been found (Greyson, 2000; Gabbard and Twemlow, 1984). Also subjects with NDEs and without NDEs were not found to differ with respect to measures of intelligence, extraversion, neuroticism, or anxiety. Unfortunately, only a small number of subjects with NDEs have been studied in this systematic manner (Locke and Shontz, 1983; Twemlow and Gabbard, 1984). However, people with NDEs were found to report the so-called paranormal experiences prior to their NDE more often (Greyson, 2003; Groth-Marnat, 1994), as well as other complex experiences such as OBEs, feelings of being united with the universe, feeling the presence of God and other wordly entities, or having past-life memories (Osis and Harraldsson, 1977). It was also noted that people with NDEs tend to report repeated OBEs and higher interest in dreams, past-lives, and meditation (Kohr, 1983), suggesting that subjects with NDEs might differ from other subjects in being more open to unusual experiences (and also willing to report these) and being attentive to the so-called inner-states (Roberts and Owen, 1988). It might also be that this personality trait is linked to the larger concept of "magical thinking," which has been shown to depend on right hemispheric activity and affinity to "paranormal" thought (Brugger and Taylor, 2003). People with NDEs as well as people with OBEs (Irwin, 1985) also score higher than control subjects on absorption (a measure that refers to the tendency to immerse in imagination and internal states) and the related trait of fantasy proneness (a tendency to have vivid hallucinations, blurred distinction between reality and imagination, enhanced sensory experiences, and heightened visual imagery) (Greyson, 2000; Twemlow and Gabbard, 1984). The fact that this personality factor is shared among subjects with OBEs and NDEs again suggests common predisposing factors. On a related note, Ring (1992) suggested that subjects with NDEs are more likely to have suffered abuse, stress, illness, and social problems during childhood than a control group (see also Irwin, 1993). Measures of dissociation (and depersonalization) have also been associated with NDEs. Subjects with NDEs scored higher than controls, but were below the range of pathological conditions on this measure (Greyson, 2000). Others also found significantly higher scores in a group of NDE subjects on the Dissociative Experiences Scale than in their control group (again these scores were different between both groups, but within the normal range) (Britton and Bootzin, 2004).

Neurology of NDEs

Although several authors have speculated on the neurology of NDEs, there is an almost complete absence of neurological data. Medical and neurological conditions that have been associated with NDEs and that are associated with brain interference or brain damage are cardiac arrest, general anesthesia, temporal lobe epilepsy, electrical brain stimulation, and sleep abnormalities (e.g., REM intrusions). As more systematic studies have focused on the investigation of the frequency and intensity of NDEs in cardiac arrest patients (Van Lommel et al., 2001; Parnia et al., 2001; Schwaninger et al., 2002; Greyson, 2003) we will start by reviewing these studies with respect to potential neurological mechanisms (see also French, 2005).

Brain Anoxia in Cardiac Arrest Patients

The data reported in a large prospective study (Van Lommel et al., 2001) describe several clinical characteristics of patients that are likely to report a NDE after cardiac arrest. In most of these patients cardiac arrest occurred in the hospital ($n = 234$; 68%) and resuscitation was initiated within 2 min after this ($n = 190$; 81%). Loss of consciousness lasted less than 5 min ($n = 187$; 80%). Yet, loss of consciousness was defined independent of a neurological examination as well as electroencephalographic (EEG) records and estimated only by electrocardiogram records. We therefore do not have detailed neurological data about brain function in the critical clinical period that is frequently assumed to be associated with NDEs. This is likely due to the medical emergency situation and lack of time to evaluate neurological function during resuscitation. Accordingly, the authors (Van Lommel et al., 2001) "defined clinical death [independent of neurological data] as a period of unconsciousness caused by insufficient blood supply to the brain because of inadequate blood circulation, breathing, or both." The remaining patients were resuscitated outside the hospital ($n = 101$; 29%) and likely suffered from longer periods of cardiac arrest ($n = 88$; 80%) and unconsciousness for more than 10 min ($n = 62$; 56%). Among all investigated patients, 36% ($n = 123$) were unconscious, as defined above, for longer than an estimated period of 60 min.

Twelve percent of the total of 344 patients investigated in that study (Van Lommel et al., 2001) reported an NDE. The data showed that younger patients with a first myocardial infarction and with a previous NDE reported NDEs more frequently, while prolonged reanimation was associated with less frequent NDEs. Moreover, male patients and patients who were reanimated outside the hospital reported less NDE elements. The authors (Van Lommel et al., 2001) argue that the diminished frequency of NDEs in patients with prolonged reanimation might be due to memory loss or deficient short-term memory in these patients. This statement seems premature since no quantitative neurological or neuropsychological assessment on short- or long-term memory were carried out (or reported) in the acute or later phases of the study. Furthermore, no EEG records and neuroimaging examinations (MRI or computer tomography) were studied and compared between cardiac arrest patients with and without NDEs. We believe that neurological and neuropsychological data as well as EEG and neuroimaging data in cardiac arrest patients with NDEs will be crucial in describing eventually some of the neurocognitive mechanisms of NDEs.

Several recent studies have reported neurological data about brain function and brain damage in patients suffering from more serious consequences of cardiac arrest such as prolonged loss of consciousness in coma, vegetative state, minimally conscious state, as well as milder associated neurological conditions (see Chapter 3). Unfortunately, we were not able to find similar studies reporting such data for cardiac arrest patients with NDEs, who are most often considered to have maintained pre-morbid brain functions (although this was not confirmed by neuropsychological testing). Given the common etiological origin, we suggest that patients with NDEs following cardiac arrest may suffer from brain damage that is milder, but anatomically similar, to the brain damage reported in patients with mild forms of postanoxic brain damage of cardiac or pulmonary origin (Ammermann et al., 2007). Data reported in the latter study showed that brain damage in such patients is symmetrical and predominantly affects gray and white matter in several cortical and subcortical regions without affecting the brainstem (Figure 20.3). These regions include the frontal and occipital cortex (including the optic radiation) as well as the hippocampus, the basal ganglia and the thalamus confirming earlier results that have also revealed damage to watershed regions such as the TPJ (Kinney and Samuels, 1994;

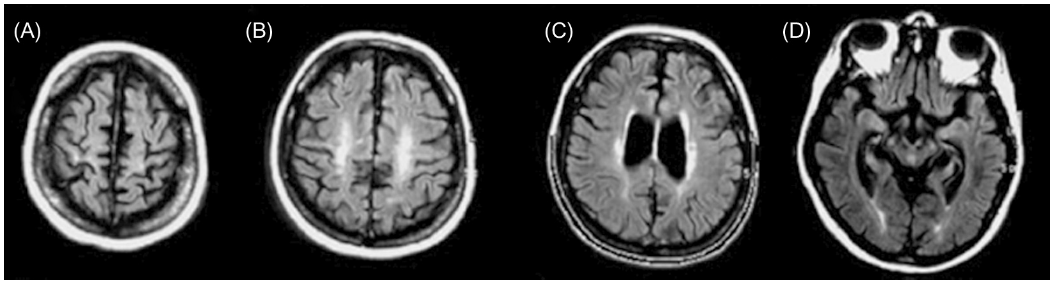

FIGURE 20.3 MRI of the brain of a cardiac arrest patient with excellent recovery. MRI reveals a distinct pattern of brain damage including white matter damage in three brain areas: in proximity of the primary motor and premotor cortex (A and B), periventricular white matter lesions (C), and in proximity of primary visual cortex including the optic radiation (D). *Source: Modified from Ammermann et al. (2007) reproduced with permission from Elsevier.*

Adams et al., 2000; Chalela et al., 2001). Importantly, damage or interference with these regions may be linked to several key features of NDEs (see below).

Another, smaller prospective study on NDEs in cardiac arrest survivors (Parnia et al., 2001) also failed to present any neuroimaging data or results of neurological, neuropsychological, or EEG examinations. We reiterate that EEG records during or immediately after the cardiac arrest period will be important as well as multi-channel EEG recordings during later periods allowing detection or exclusion of more subtle potential abnormalities and their correlation with potential neurological, neuropsychological, and neuroimaging abnormalities. In addition, the patient sample was small and only four cardiac arrest patients (6%) reported NDEs (as defined by the NDE scale described in Greyson, 1983). A third study (Schwaninger et al., 2002) not only found that NDEs occurred with a frequency of 23% in the same clinical population, but also did not report neurological, neuropsychological, EEG, or neuroimaging data. A final study (Greyson, 2003) found a frequency of 10% and found no differences in cognitive functions between cardiac arrest patients with and without NDEs. For the cognitive examination the investigators applied the mini mental status that is often used for brief clinical pre-evaluations of patients with dementia (Folstein et al., 1975). Although the latter test revealed normal performance in cardiac arrest patients with and without NDEs (score of ~27) this examination does not permit detailed testing of memory, language, spatial thought, visual, auditory, attention, and executive functions as is done with standard neuropsychological examinations. Despite the variability in frequency estimations of NDEs in cardiac arrest survivors in these four studies the two larger studies seem to agree on 10−12%, but unfortunately do not provide any empirical data on the neurology of NDEs.

Other MRI-based techniques might allow describing potential brain damage in cardiac arrest patients with NDEs. Thus, diffusion-weighted MRI allows the detection of focal cerebral infarctions in the acute phase (Moseley et al., 1990; Röther et al., 1996), due to its sensitivity for ischemia-induced changes in water diffusion (Fiehler et al., 2002). Els et al. (2004) have shown that diffusion-weighted MRI may allow to reveal correlates of cerebral anoxia in cardiac arrest patients independent of severity of anoxia, that is, even in patients who recover very well (Figure 20.4). Moreover, standard T1 and T2 weighted MRI may not always reveal brain damage in these patients. It thus seems that different techniques of MRI in the acute as well as the chronic phase in such patients will be necessary to reveal potential functional and structural lesions causing distinct features of NDEs.

Several authors have argued that brain anoxia may account for the auditory, visual, and memory aspects of NDEs (heard noises, perceived lights and tunnels, life review, encounters). The mechanisms involved have been proposed to occur as a cascade of events, beginning by a neuronal disinhibition in early visual cortex spreading to other cortical areas leading to NDE features such as tunnel vision and lights (Woerlee, 2005; Blackmore, 1993; Rodin, 1980; Saavedra-Aguilar and Gómez-Jeria, 1989). However, the actual sequence of NDE features remains an unexplored area. Based on the reviewed data, it seems clinically plausible that cardiac arrest patients with NDEs may suffer from acute or chronic damage or interference with a subset of widespread cortical and subcortical areas, including gray and white matter, that have been described in cardiac arrest patients. Especially, damage to bilateral occipital cortex and the optic radiation (Figures 20.3D and 20.4C) may lead to the visual features of NDEs such as seeing the tunnel or surrounding darkness (i.e., bilateral peripheral visual field loss) and lights (damage to the optic radiation is often associated with macular sparing and hence centrally preserved vision), whereas interference with the hippocampus may lead to heightened emotional experiences and experiential phenomena due to epileptogenic interference,

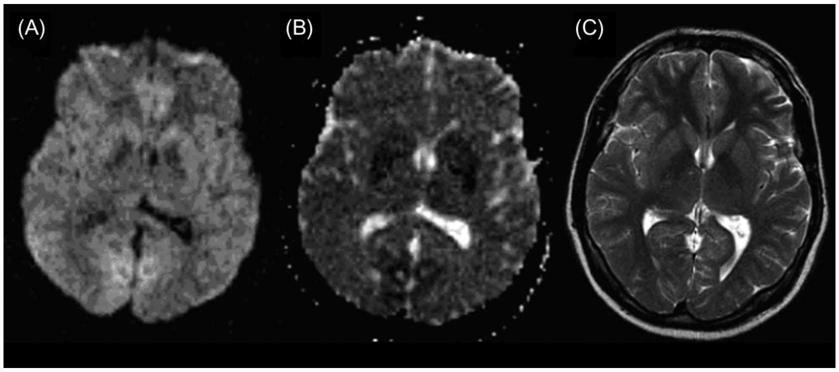

FIGURE 20.4 MRI of the brain of a cardiac arrest patient with excellent recovery. Whereas standard T2-weighted MRI (Figure 20.4C; compare to Figure 20.3) did not reveal any abnormalities, diffusion-weighted MRI in the acute phase (15 h after resuscitation) revealed MRI abnormalities that are compatible with bilateral brain damage. These are shown in Figure 20.4A and consist of bilateral hyperintense damage in proximity to primary visual cortex and the optic radiation (compare also with Figure 20.3D). In addition, the apparent diffusion coefficient (ADC; Figure 20.4B) maps showed prominent signal decrease in the same locations as DWI, compatible with ischemic brain damage. *Source: Modified from Els et al. (2004) with permission from Blackwell Publishing.*

including memory flashbacks and the life review (see below). Moreover, interference with the right TPJ may lead to OBEs (Blanke et al., 2002, 2004; Blanke and Mohr, 2005) whereas interference with the left TPJ may cause the feeling of a presence and meeting of spirits, and heautoscopy (Arzy et al., 2006; Brugger et al., 1996). This proposition extends previous postanoxic accounts of NDEs by linking the different features to different brain regions that may be damaged in cardiac arrest patients with rapid recovery of consciousness and neuropsychological functioning. These speculations have to be regarded with caution, as to date, no neurological, neuropsychological, and neuroimaging data exist to corroborate this claim empirically. We also note that models only based on the pathophysiology of brain anoxia do not account for NDEs occurring in situations that are not related to cardiac arrest such as polytraumatism, general anesthesia, and hypoglycemia. Nor do they account for NDEs occurring during mountain falls as well as other fearful situations leading to NDEs (Blackmore, 1993; Roberts and Owen, 1988). As stated by Blackmore (1993), brain anoxia is probably one of several, related, mechanisms that lead to NDEs.

Experimental Brain Hypoxia in Healthy Subjects

Lempert et al. (1994) induced syncopes in 42 healthy subjects using cardiovascular manipulations (hyperventilation, orthostasis, Valsalva maneuvers) with the aim of investigating the symptoms of transient cerebral hypoxia. They found that many of their subjects reported NDE-like sensations: 16% had OBEs, 35% feelings of peace and painlessness, 17% saw lights, 47% reported entering another world, 20% encountered unfamiliar beings and 8% had a tunnel experience. Two subjects were even reminded of previous spontaneous NDEs. These data suggest that NDEs may be approached experimentally in healthy subjects although anxiety, vagal effects, as well as other non-hypoxia related mechanisms may also play an important role (Lempert et al., 1994).

General Anesthesia

NDEs may also occur during general anesthesia. Thus, Cobcroft and Forsdick (1993) have reported patients who experienced OBEs during general anesthesia as well as sensations of moving in a tunnel, seeing people and operating theater details, and seeing bright lights, and surrounding whiteness. This was found in 4% of a large sample of patients having undergone general anesthesia and was confirmed by other investigators (Parnia et al., 2001; Schwaninger et al., 2002). There is also a report of a NDE in a 12-year-old boy (known for mild cerebral palsy) who underwent general anesthesia for elective uncomplicated surgery (Lopez et al., 2006). Monitoring during general anesthesia did not reveal any signs of awakening, hypoxia, ischemia, or hypoglycemia. Yet, this young patient, who did not know about NDEs, reported the following "strange dream": "I was sleeping and suddenly I felt awake and had the impression that I was leaving my body... I could see from above my whole body lying on the back on the operating table ... and surrounded by many doctors ... I felt as being above my physical body ... I was like a spirit ... and I was floating under the ceiling of the room. ... but then I had a sensation of lightness ... and I felt relaxed and comfortable... I had the impression that everything was real ... I then saw a dark tunnel in front of me ... and I felt attracted to it ... I passed through the tunnel very fast and at its end I saw ... a bright light ... I heard noises ...[and] voices ...."

Interestingly, anesthetic agents such as propofol (as applied in this patient) are known to have neuroexcitatory effects (Walder et al., 2002) inducing in some patients seizure-like activity and decreased metabolism in the dorsolateral prefrontal cortex, posterior parietal cortex (including the TPJ), and temporal lobe (Veselis et al., 2002). Lopez et al. (2006) speculated accordingly that interferences of anesthetic agents in these areas may lead to the induction of some features of NDE, such as OBEs, feelings of a presence, and meeting of spirits.

Independent of general anesthesia, substances such as ketamine, LSD, and cannabinoids, as well as many others (Jansen, 1997; Carr, 1982; Saavedra-Aguilar and Gómez-Jeria, 1989) may also lead to experiences resembling some of the NDE features, like the feelings of joy and bliss, visual hallucinations (including tunnels, lights, and people), transcendental elements (Jansen, 1997; Siegel, 1980), and OBEs (Bünning and Blanke, 2005; Tart, 1971). Feelings that the experience is veridical are not rare when using such substances, as well as the impression of "mental clarity" and enhanced cognition (Jansen, 1997). Other authors argued that drug administration, instead of facilitating NDEs, may also diminish their frequency (Ring, 1982; Sabom, 1982) or have no effect on the frequency of NDEs (in cardiac arrest patients; Van Lommel et al., 2001; Greyson, 2003).

Epilepsy and Brain Stimulation

Many observations link NDEs to epilepsy and especially to complex partial seizures. This evidence includes (i) interictal EEG signs (spikes and spike-waves) in subjects with NDEs, (ii) interictal manifestations such as the interictal temporal lobe syndrome, (iii) similarity of NDEs with several known sensory and cognitive ictal symptoms, (iv) experimental induction of some of these symptoms by electrical cortical stimulation in awake humans, (v) and frequent damage to the hippocampus, a major epileptogenic region, in cardiac arrest patients.

Whereas the neurological examination is frequently normal in patients with temporal lobe epilepsy, neuropsychological examinations often reveal mild to moderate memory impairments characterized by deficits in learning, recognition, delayed recall, or fluency tasks either for verbal or visuo-spatial material (Pegna et al., 1998; Flügel et al., 2006). Moreover, these distinct memory deficits have been correlated with hippocampal sclerosis, decreased volume, and metabolic changes of this structure, as shown by functional MRI, magnetic resonance volumetry, and magnetic resonance spectroscopy (Pegna et al., 2002; Zubler et al., 2003). Such examinations in cardiac arrest patients with NDEs might thus reveal similar circumscribed deficits and brain damage, at least in some of these patients.

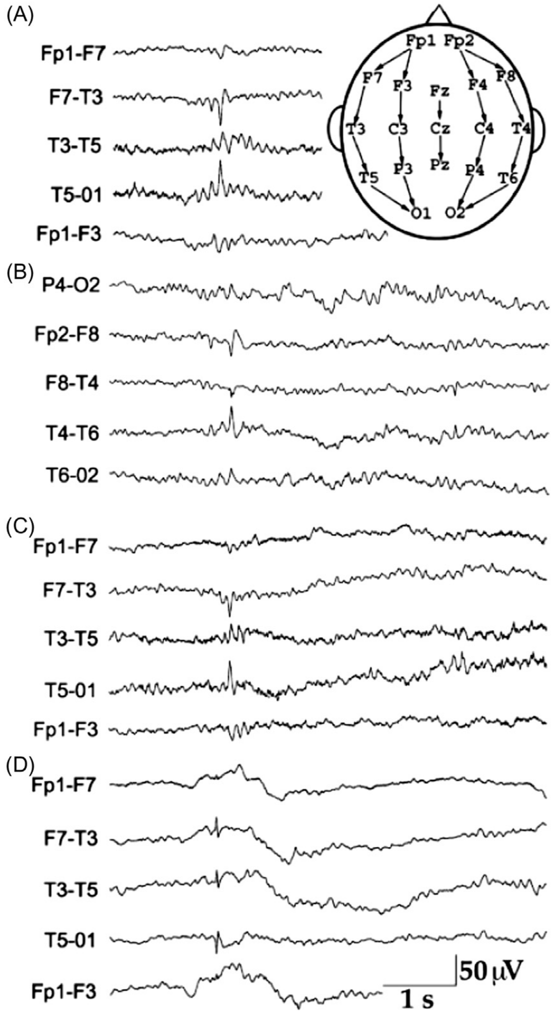

FIGURE 20.5 Examples of interictal epileptiform discharges in the temporal lobe of subjects with NDE. (A)–(C) Stage 2 sleep; (D) REM sleep. The illustration of the head shows the placement of the electrodes in the 10–20 system with an anterior–posterior bipolar reference scheme. Each tracing shows the localized brain activity from the area of the two electrodes indicated. *Source: From Britton and Bootzin (2004); with permission from Blackwell Publishing.*

EEG recordings in healthy subjects who have reported NDE previously have been carried out and suggested the presence of abnormal epileptic interictal EEG activity over the left mid-temporal region in 22% of subjects (one subject had bilateral abnormal activity) (Britton and Bootzin, 2004). No epileptic seizures were recorded or reported by any of the subjects. Abnormal activity was most prominent over mid-temporal regions and characterized by spikes and spike-waves, as well as sharp waves (Figure 20.5). The authors added that subjects with NDE also reported more often than the control group several temporal lobe symptoms (Figure 20.6) compatible with the interictal temporal lobe syndrome (Waxman and Geschwind, 1975). These include deepened emotionality, nascent

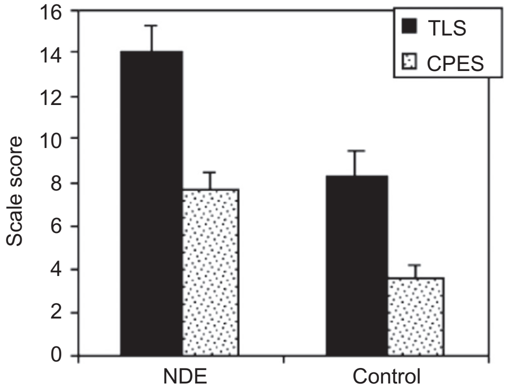

FIGURE 20.6 Symptoms evocative of interictal and ictal temporal lobe syndrome in subjects with NDE. Scores on the temporal lobe symptoms (TLS) and complex partial epileptic signs (CPES) subscales of the Personal Philosophy Inventory (Persinger, 1983) in subjects with NDE and a control group of age and gender matched participants with no history of life-threatening event. Items include experiences of sleepwalking, olfactory hypersensitivity, hypergraphia, feelings of intense personal significance, and unusual perceptions. *Source: From Britton and Bootzin (2004); with permission from Blackwell Publishing.*

religious interest, enhanced philosophical preoccupation, moralism, sense of personal destiny, as well as others (although patients with temporal lobe epilepsy may not always show these signs (Blumer, 1998; Schomer et al., 2000; Trimble and Freeman, 2006)). Finally, abnormal epileptic activity in subjects with previous NDEs (Britton and Bootzin, 2004) was correlated with their score on an NDE scale (Greyson, 1983), but not with trauma-related measures such as posttraumatic stress disorder, dissociation, or previous head trauma.

Many features of the NDE have been described as symptoms of epileptic seizures and have also been induced in a controlled fashion by electrical cortical stimulation. Thus, direct electrical cortical stimulation (Blanke et al., 2002; Penfield, 1955) and focal epileptic activity at the TPJ (Blanke et al., 2004; Devinsky et al., 1989) may induce OBEs as well as vestibular sensations (Blanke et al., 2002, 2004; Penfield, 1955; Kahane et al., 2003). Interestingly, in a small study (Hoepner et al., 2013), five patients with OBE and autoscopy of ictal origin involving the TPJ or adjacent regions reported significantly higher scores on Greyson's NDE Questionnaire than a control group of 12 patients with temporal lobe seizure preceded by aura, but no ictal autoscopy phenomena, involving mesio-temporal pathologies. Notably, all ictal autoscopy patients, but no patients in the control group, reported scores equal or higher to the cut-off defining the NDE. It thus seems that current measures are unable to distinguish OBEs of ictal origin from NDEs, which suggests common mechanisms between both conditions. Memory flashbacks and life reviews have long been known to occur as a symptom of temporal lobe epilepsy and are generally referred to as experiential phenomena (Penfield and Jasper, 1954; Halgren et al., 1978; Gloor, 1990; Bancaud et al., 1994). Experiential phenomena have also been induced by electrical cortical stimulation of the temporal lobe, the hippocampus, and the amygdala (Halgren et al., 1978; Gloor, 1990; Bancaud et al., 1994; Gloor et al., 1982), as well as the frontal cortex (Bancaud and Talairach, 1991; Chauvel et al., 1995; Blanke et al., 2000). One of Hughlings Jackson's (1888) patients with temporal lobe epilepsy describes an ictal life review: "The past is as if present, a blending of past ideas with present. . .a peculiar train of ideas of the reminiscence of a former life, or rather, perhaps, of a former psychologic state" (quoted in Hogan and Kaiboriboon, 2003, p. 1741). More recently, Vignal et al. (2007) re-investigated memory flashbacks and life reviews in patients with pharmacoresistant epilepsy during spontaneous seizures and by electrical cortical stimulation with intracranial electrodes. Among a population of 180 subjects, they found 17 patients that described 55 memory flashbacks. These were quite variable, but could be repeatedly evoked in a given subject by the electrical stimulation of specific areas. Within the temporal cortex, Vignal et al. (2007) evoked memory flashbacks and life reviews by electrical stimulation of the amygdala, the hippocampus and the parahippocampal gyrus. One evoked memory flashback was: ". . .it is always thoughts from childhood, it is always visual, it is a place behind the house, the field were my father put his car, near a lake. . .Yes, it is pleasant because we were going to get the car from behind the house, it is a happy memory, it is never unpleasant" (Vignal et al., 2007, p. 92). Similar observations have been reported earlier by Penfield and Jaspers (1954) by electrical stimulation of the lateral temporal cortex. This suggests that both the stimulation of medial and lateral temporal structures can be at the origin of experiential phenomena including memory flashbacks and life review. Another feature of the NDE that can be observed in epileptic seizures and by electrical cortical stimulation is the feeling of a presence, namely the experience of feeling and believing that someone is nearby, without being able to see this person (Brugger et al., 1996; Jasper, 1913; Lhermitte, 1951; Critchley, 1979; Blanke et al., 2003) In one patient with pharmacoresistant epilepsy (Arzy et al., 2006), the feeling of a presence was induced by electrical cortical stimulation during presurgical epilepsy evaluation. The patient reported an "illusory shadow," who mimicked her body position and posture when her left TPJ was stimulated. She also reported a negative feeling about the experience, sensing hostile intentions from this unfamiliar "shadow." The feeling of a presence (in neurological or psychiatric patients) may also be quite elaborated and the felt person may be identified or interpreted as a mystical or supreme entity, or guardian angel (Blanke et al., 2004 (case 5); Lunn, 1970; Brugger et al., 1996; for a more recent study see Blanke et al., 2014). The seen double during heautoscopy has also been linked to the left TPJ and may also be experienced as a mystical or supreme entity (Blanke et al., 2004; case 4; Blanke and Mohr, 2005). The experience of such a heautoscopic double may be of great emotional and personal relevance (Brugger, 2002; Brugger et al., 1996), as witnessed by the frequent inclusion of similar experiences in romantic and gothic literature (Dieguez, 2013). Also, heautoscopy is often associated with the experience of sharing of thoughts, words, or actions with the double or other people. Thus, patients with heautoscopy (but not OBEs) experience to hear the autoscopic body talk to them (Brugger et al., 1994) or experience that they communicate with the illusory body by thought (Blanke et al., 2004; case 5) a finding reminiscent of people reporting about the meeting of spirits during NDEs. Other patients with heautoscopy stated that the autoscopic body is performing the actions they were supposed to do (Devinsky et al., 1989; case 9) or fights with other people that could be of potential danger to the patient (Devinsky et al., 1989; case 5).

To summarize, the NDE features OBE, feeling of presence, meeting with spirits, memory flashbacks and life review are well-known symptoms of epileptic discharge or electrical stimulation of hippocampus, amygdala, and parahippocampal gyrus as well as more lateral, neocortical temporal areas including the TPJ. The most common cause of temporal lobe epilepsy is hippocampal dysplasia and sclerosis following brain anoxia, as the hippocampus is one of the most anoxia-sensitive brain regions in humans, and is damaged in almost all patients with cardiac arrest (as well as the TPJ which is a classical watershed region). Although more empirical investigations on this issue are needed, interference and damage to hippocampus and TPJ and consequently clinical and subclinical partial epileptic seizures manifestations thus seem likely candidates as major mechanisms of NDEs.

Sleep Abnormalities and Brainstem Mechanisms

Recently it has been suggested that subjects with NDEs report more frequently symptoms that might be associated with a sleep disorder associated with REM intrusions as compared to age-matched control subjects without NDEs (Nelson et al., 2006, 2007) (see Chapter 8 for more details on REM sleep). This was especially the case in subjects who had NDEs with OBEs (whether as part of their NDE or occurring at a different time (Nelson et al., 2007)). REM intrusions were estimated based on questions such as "Just before falling asleep or just after awakening, have you ever seen things, objects or people that others cannot see?" and "Have you ever awakened and found that you were unable to move or felt paralyzed?." Both items were reported significantly more often in subjects with NDEs. Visual and auditory hallucinations were also reported to be more frequent in subjects with OBEs during NDEs. The authors (Nelson et al., 2006, 2007) suggest that NDEs and OBEs may be related to muscular atonia during REM intrusions due to abnormal brainstem processing. REM intrusions are relatively frequent in the normal population and associated with sleep paralysis (a temporary paralysis of the body during sleep-wake transitions) in about 6% of the population. Symptoms similar to NDEs are also found in other medical conditions involving sleep or brainstem disturbances such as narcolepsy (a disorder involving excessive daytime sleepiness; Overeem et al., 2001), peduncular hallucinations (Manford and Andermann, 1998), hypnagogic and hypnopompic hallucinations (Takata et al., 1998), as well as sleep paralysis (Cheyne, 2005). Finally, patients with Guillain-Barré syndrome (an acute autoimmune disturbance of the peripheral nervous system leading in some cases to severe peripheral sensorimotor deficits that may require intensive care) have also been reported to have OBEs as well as NDE-like features (Cochen et al., 2005). In a series of 139 such patients, mental disturbances have been found in 31% and included vivid and unusual dreams, visual illusions and hallucinations, as well as paranoid delusions. The investigators did not inquire about OBEs directly, but patients reported related phenomena such as vivid or dreamlike sensations of losing the sense of one's body, meeting people, hovering or floating weightlessly over their body, or having the impression to have left one's body. Moreover, patients with the Guillain-Barré syndrome also reported complex own body illusions that have been linked functionally to OBEs such as illusory body-part dislocations, the inversion illusion, and room-tilt illusion (Blanke et al., 2004; Lopez and Blanke, 2007).

COGNITIVE NEUROSCIENCE OF NDE PHENOMENA

The reviewed data suggest that many functional and neural mechanisms are involved in the generation of the wide range of phenomena grouped under the term NDE. These mechanisms include mainly visual, vestibular, multisensory, memory, and motor mechanisms. Concerning brain regions the reviewed studies suggested damage to or interference with different cortical, subcortical, and brainstem areas, as well as the peripheral nervous system. Interference with the functioning of this extended network also seems to occur in situations characterized by stress, physical exhaustion, rapid accelerations or decelerations, and deliberate relaxation. Although the neural mechanisms of many illusions and hallucinations have been described in detail, there are—at this stage—only preliminary data on the neurology of the different phenomena associated with NDEs. Systematic neurological research is needed to fill this gap as has already been done for related experiences (such as the OBE) or related medical conditions in cardiac arrest patients (coma, vegetative state, minimally conscious states). Although abnormalities in brainstem and peripheral nervous system may lead to NDE phenomena, we argue that major insights into these experiences will be gained by applying research techniques from cognitive neurology and cognitive neuroscience in order to reveal their cortical and subcortical mechanisms. We have reviewed evidence that suggests that some NDE phenomena can be linked to distinct brain mechanisms. This was shown for the OBE (damage to right TPJ), tunnel vision and seeing of foveal lights (bilateral occipital damage including the optic radiation with macular sparing or foveal hallucinations), feeling of a presence and meeting of spirits (damage to left TPJ), as well as memory flashbacks, life review, and enhanced emotions (hippocampal and amygdala damage). All structures have been shown to be frequently damaged in those cardiac arrest patients that show excellent recovery and who are so far the best studied patient group with NDE phenomena.

Based on the selective sites of brain damage in cardiac arrest patients (with excellent recovery) and the associations of key NDE phenomena to some of these same areas we would like to suggest that two main types of NDEs exist, depending of the predominantly affected hemisphere. We propose that type 1 NDEs are due to bilateral frontal and occipital, but predominantly right hemispheric brain damage affecting the right TPJ and characterized by OBEs, altered sense of time, sensations of flying, lightness, vection and silence. Type 2 NDEs are also due to bilateral frontal and occipital, but predominantly left hemispheric brain damage affecting the left TPJ and characterized by feeling of a presence, meeting of and communication with spirits, seeing of glowing bodies, as well as voices, sounds, and music without vection. We expect emotions and life review (damage to unilateral or bilateral temporal lobe structures such as the hippocampus and amygdala) as well as lights and tunnel vision (damage to bilateral occipital cortex) to be associated with type 1 and type 2 NDEs alike. Unfortunately, the few existing empirical studies on NDEs in patients with well-defined medical conditions lack neurological, neuropsychological, neuroimaging, and EEG data and to our knowledge no phenomenological analysis of case collections has tried to differentiate the two different types of NDEs in the way we are proposing here. Our proposition remains therefore speculative. We are confident that future neuroscientific studies in cardiac arrest patients with NDEs are likely to reveal the functional neuroanatomy of several NDE phenomena, likely implicating distributed bilateral cortical and subcortical brain mechanisms. There are also the promising experimental results and earlier suggestions (Britton and Bootzin, 2004; Persinger, 1994) that link NDE phenomena to symptoms of temporal lobe epilepsy. We therefore also expect additional insights into the neural and neuropsychological mechanisms of NDE phenomena through studies investigating the incidence of NDE phenomena (by carrying out detailed interviews and questionnaires) in patients with focal epilepsies as well as other neurological patients suffering from focal brain damage.

CONCLUSION

The present chapter has summarized findings on the functional and neural mechanisms of OBEs and NDEs. Whereas OBEs and their underlying brain mechanisms are currently investigated by several research groups and point to the importance of bodily multisensory integration at the right TPJ, the data on the neural mechanisms of NDEs are extremely sparse or altogether absent. We have argued above that the investigation of NDEs in cardiac arrest patients as well as neurological patients may be one possibility to start investigating the functional and neural mechanisms of NDEs. We agree with Christopher French (2005) who suggested that “given the heterogenous nature of the NDE . . . [t]here is no reason to assume that a single comprehensive theory will explain the entire phenomenon.” We add that there is also no reason to assume that an NDE is just one phenomenon, but rather a group of loosely associated experiences due to interference with different brain functions and brain mechanisms. Yet, after countless speculations that have focused on “life after life” and “survival of bodily death” in “survivors” of life-threatening situations, we propose that future studies on NDEs may want to focus on the functional and neural mechanisms of NDE phenomena in patient populations as well as healthy subjects. This might eventually lead to the demystification of NDEs, at least partly. More importantly, the scientific study of these varied complex experiences may allow studying the functional and neural mechanisms of beliefs, personality, spirituality, and self that have and will continue to intrigue scientists, scholars, and laymen alike.

References

Adams, J.H., Graham, D.I., Jennett, B., 2000. The neuropathology of the vegetative state after an acute brain insult. Brain. 123 (7), 1327−1338.

Aizenberg, D., Modai, I., 1985. Autoscopic and drug-induced perceptual disturbances. Psychopathology. 18 (5−6), 237−240.

Alvarado, C.S., 2000. Out-of-body experiences. Varieties of Anomalous Experiences. American Psychological Association, Washington, DC, pp. 183−218.

Alvarado, C.S., 2001. Features of out-of-body experiences in relation to perceived closeness to death. J. Nerv. Ment. Dis. 189 (5), 331−332.

Ammermann, H., Kassubek, J., Lotze, M., Gut, E., Kaps, M., Schmidt, J., et al., 2007. MRI brain lesion patterns in patients in anoxia-induced vegetative state. J. Neurol. Sci. 260 (1), 65−70.

Arzy, S., Seeck, M., Ortigue, S., Spinelli, L., Blanke, O., 2006. Induction of an illusory shadow person. Nature. 443 (7109), 287.

Arzy, S., Mohr, C., Michel, C.M., Blanke, O., 2007. Duration and not strength of activation in temporo-parietal cortex positively correlates with schizotypy. Neuroimage. 35 (1), 326−333.

Aspell, J.E., Heydrich, L., Marillier, G., Lavanchy, T., Herbelin, B., Blanke, O., 2013. Turning body and self inside out visualized heart-beats alter bodily self-consciousness and tactile perception. Psychol. Sci. Available from: http://dx.doi.org/10.1177/0956797613498395.

Astafiev, S.V., Stanley, C.M., Shulman, G.L., Corbetta, M., 2004. Extrastriate body area in human occipital cortex responds to the performance of motor actions. Nat. Neurosci. 7 (5), 542−548.

Bancaud, J., Talairach, J., 1991. Clinical semiology of frontal lobe seizures. Adv. Neurol. 57, 3−58.

Bancaud, J., Brunet-Bourgin, F., Chauvel, P., Halgren, E., 1994. Anatomical origin of déjà vu and vivid "memories" in human temporal lobe epilepsy. Brain. 117 (1), 71−90.

Barrett, S.W., 1926. Death-Bed Visions. Methuen, London, England.

Benson, A.J., 1999. Spatial disorientation—common illusions, third ed. Aviation Medicine, vol. 1. Butterworth & Heinmann, Oxford, pp. 437−454.

Blackmore, S., 1986. Out-of-body experiences in schizophrenia a questionnaire survey. J. Nerv. Ment. Dis. 174 (10), 615−619.

Blackmore, S., 1992. Beyond the Body: An Investigation of Out-of-Body Experiences. Academy Chicago Publications.

Blackmore, S., 1993. Dying to Live: Near-Death Experiences. Prometheus books.

Blackmore, S., 1994. Out-of-body experiences and confusion-ism: A response to Woodhouse. New Ideas Psychol. 12, 27−30.

Blackmore, S., 2013. Consciousness: An Introduction. Oxford University Press, Oxford.

Blanke, O., 2012. Multisensory brain mechanisms of bodily self-consciousness. Nat. Rev. Neurosci. 13 (8), 556−571.

Blanke, O., Arzy, S., 2005. The out-of-body experience: disturbed self-processing at the temporo-parietal junction. Neuroscientist. 11 (1), 16−24.

Blanke, O., Mohr, C., 2005. Out-of-body experience, heautoscopy, and autoscopic hallucination of neurological origin: implications for neurocognitive mechanisms of corporeal awareness and self-consciousness. Brain Res. Rev. 50 (1), 184−199.

Blanke, O., Perrig, S., Thut, G., Landis, T., Seeck, M., 2000. Simple and complex vestibular responses induced by electrical cortical stimulation of the parietal cortex in humans. J. Neurol. Neurosurg. Psychiatry. 69 (4), 553−556.

Blanke, O., Ortigue, S., Landis, T., Seeck, M., 2002. Neuropsychology: stimulating illusory own-body perceptions. Nature. 419 (6904), 269−270.

Blanke, O., Ortigue, S., Coeytaux, A., Martory, M.-D., Landis, T., 2003. Hearing of a presence. Neurocase. 9 (4), 329−339.

Blanke, O., Landis, T., Spinelli, L., Seeck, M., 2004. Out-of-body experience and autoscopy of neurological origin. Brain. 127 (Pt 2), 243−258.

Blanke, O., Pozeg, P., Hara, M., Heydrich, L., Serino, A., Yamamoto, A., et al., 2014. Neurological and robot-controlled induction of an apparition. Curr. Biol. 24 (22), 2681−2686.

Blumer, D., 1998. Evidence supporting the temporal lobe epilepsy personality syndrome. Neurology. 53 (5 Suppl. 2), S9−S12.

Braithwaite, J.J., Samson, D., Apperly, I., Broglia, E., Hulleman, J., 2011. Cognitive correlates of the spontaneous out-of-body experience (OBE) in the psychologically normal population: evidence for an increased role of temporal-lobe instability, body-distortion processing, and impairments in own-body transformations. Cortex. 47 (7), 839−853.

Brandt, T., 1999. Central vestibular disorders, Vertigo: Its Multisensory Syndromes, second ed. Springer, London, pp. 167−246.

Britton, W.B., Bootzin, R.R., 2004. Near-death experiences and the temporal lobe. Psychol. Sci. 15 (4), 254−258.

Brugger, P., 2002. Reflective mirrors: perspective-taking in autoscopic phenomena. Cogn. Neuropsychiatry. 7 (3), 179−194.

Brugger, P., Taylor, K.I., 2003. ESP: extrasensory perception or effect of subjective probability? J. Conscious. Stud. 10 (6−7), 221−246.

Brugger, P., Agosti, R., Regard, M., Wieser, H.-G., Landis, T., 1994. Heautoscopy, epilepsy, and suicide. J. Neurol. Neurosurg. Psychiatry. 57 (7), 838−839.

Brugger, P., Regard, M., Landis, T., 1996. Unilaterally felt "presences": the neuropsychiatry of one's invisible doppelganger. Cogn. Behav. Neurol. 9 (2), 114−122.

Brugger, P., Regard, M., Landis, T., 1997. Illusory reduplication of one's own body: phenomenology and classification of autoscopic phenomena. Cogn. Neuropsychiatry. 2 (1), 19−38.

Brugger, P., Regard, M., Landis, T., Oelz, O., 1999. Hallucinatory experiences in extreme-altitude climbers. Cogn. Behav. Neurol. 12 (1), 67−71.

Bünning, S., Blanke, O., 2005. The out-of body experience: precipitating factors and neural correlates. Prog. Brain Res. 150, 331−350.

Carr, D., 1982. Pathophysiology of stress-induced limbic lobe dysfunction: a hypothesis for NDEs. Anabiosis J. Near Death Stud. 2, 75−89.

Chalela, J.A., Wolf, R.L., Maldjian, J.A., Kasner, S.E., 2001. MRI identification of early white matter injury in anoxic—ischemic encephalopathy. Neurology. 56 (4), 481−485.

Charland-Verville, V., Jourdan, J.-P., Thonnard, M., Ledoux, D., Donneau, A.-F., Quertemont, E., et al., 2014. Near-death experiences in non-life-threatening events and coma of different etiologies. Front. Hum. Neurosci. 8, 203.

Chauvel, P., Kliemann, F., Vignal, J.P., Chodkiewicz, J.P., Talairach, J., Bancaud, J., 1995. The clinical signs and symptoms of frontal lobe seizures. Phenomenology and classification. Adv. Neurol. 66, 115.

Cheyne, J.A., 2005. Sleep paralysis episode frequency and number, types, and structure of associated hallucinations. J. Sleep Res. 14 (3), 319−324.

Clark, B., Graybiel, A., 1957. The break-off phenomenon: a feeling of separation from the earth experienced by pilots at high altitude. J. Aviat. Med. 28 (2), 121.

Cobcroft, M.D., Forsdick, C., 1993. Awareness under anaesthesia: the patients' point of view. Anaesth. Intensive Care. 21 (6), 837−843.

Cochen, V., Arnulf, I., Demeret, S., Neulat, M.L., Gourlet, V., Drouot, X., et al., 2005. Vivid dreams, hallucinations, psychosis and REM sleep in Guillain−Barre syndrome. Brain. 128 (11), 2535−2545.

Corazza, O., Schifano, F., 2010. Near-death states reported in a sample of 50 misusers. Subst. Use Misuse. 45 (6), 916−924.

Craig, A.D.B., 2009. How do you feel—now? The anterior insula and human awareness. Nat. Rev. Neurosci. 10, 59−70.

Critchley, H.D., Wiens, S., Rotshtein, P., Öhman, A., Dolan, R.J., 2004. Neural systems supporting interoceptive awareness. Nat. Neurosci. 7 (2), 189−195.

Critchley, M., 1979. The Divine Banquet of the Brain and other Essays. Raven Press, New York, NY.

Crookall, R., 1964. More Astral Projections: Analyses of Case Histories. Aquarian Press, London.

Daly, D., 1958. Ictal affect. Am. J. Psychiatry. 115 (2), 97−108.

Damasio, A., Dolan, R.J., 1999. The feeling of what happens. Nature. 401 (6756), 847.

Dening, T.R., Berrios, G.E., 1994. Autoscopic phenomena. Br. J. Psychiatry. 165 (6), 808−817.

Devinsky, O., Feldmann, E., Burrowes, K., Bromfield, E., 1989. Autoscopic phenomena with seizures. Arch. Neurol. 46 (10), 1080.

Dieguez, S., 2010. "A man can be destroyed but not defeated": Ernest Hemingway's near-death experience and declining health. Front. Neurol. Neurosci. 27, 174−206.

Dieguez, S., 2013. Doubles everywhere: literary contributions to the study of the bodily self. Front. Neurol. Neurosci. 31, 77−115.

Dlin, B.M., 1980. The experience of surviving almost certain death. Adv. Psychosom. Med. 10, 111.

Downing, P.E., Jiang, Y., Shuman, M., Kanwisher, N., 2001. A cortical area selective for visual processing of the human body. Science. 293 (5539), 2470−2473.

Drab, K.J., 1981. The tunnel experience: reality or hallucination? Anabiosis J. Near Death Stud. 1, 126−152.

Ehrenwald, J., 1974. Out-of-the-body experiences and the denial of death. J. Nerv. Ment. Dis. 159 (4), 227−233.

Ehrsson, H.H., 2007. The experimental induction of out-of-body experiences. Science. 317 (5841), 1048.

Els, T., Kassubek, J., Kubalek, R., Klisch, J., 2004. Diffusion-weighted MRI during early global cerebral hypoxia: a predictor for clinical outcome? Acta Neurol. Scand. 110 (6), 361−367.

Fenwick, P.B.C., Fenwick, E., 1997. The Truth in the Light: An Investigation of Over 300 Near-Death Experiences. Berkley Books, New York, NY.

Fiehler, J., Fiebach, J.B., Gass, A., Hoehn, M., Kucinski, T., Neumann-Haefelin, T., et al., 2002. Diffusion-weighted imaging in acute stroke—a tool of uncertain value? Cerebrovasc. Dis. 14 (3−4), 187−196.

Firth, P.G., Bolay, H., 2004. Transient high altitude neurological dysfunction: an origin in the temporoparietal cortex. High Alt. Med. Biol. 5 (1), 71−75.

Flügel, D., O'Toole, A., Thompson, P.J., Koepp, M.J., Cercignani, M., Symms, M.R., et al., 2006. A neuropsychological study of patients with temporal lobe epilepsy and chronic interictal psychosis. Epilepsy Res. 71 (2), 117−128.

Folstein, M.F., Folstein, S.E., McHugh, P.R., 1975. Mini-mental state: a practical method for grading the cognitive state of patients for the clinician. J. Psychiatr. Res. 12 (3), 189−198.

French, C.C., 2005. Near-death experiences in cardiac arrest survivors. Prog. Brain Res. 150, 351−367.

Gabbard, G.O., Twemlow, S.W., 1984. With the Eyes of the Mind: An Empirical Analysis of Out-of-Body States. Praeger, New York, NY.

Gabbard, G.O., Twemlow, S.W., Jones, F.C., 1981. Do "Near Death Experiences" occur only near death? J. Nerv. Ment. Dis. 169 (6), 374−377.

Gloor, P., 1990. Experiential phenomena of temporal lobe epilepsy facts and hypotheses. Brain. 113 (6), 1673−1694.

Gloor, P., Olivier, A., Quesney, L.F., Andermann, F., Horowitz, S., 1982. The role of the limbic system in experiential phenomena of temporal lobe epilepsy. Ann. Neurol. 12 (2), 129−144.

Green, C.E., 1968. Out-of-the-Body Experiences. Hamish Hamilton, London.

Greyson, B., 1983. The near-death experience scale: construction, reliability, and validity. J. Nerv. Ment. Dis. 171 (6), 369−375.

Greyson, B., 1985. A typology of near-death experience. Am. J. Psychiatry. 142, 967−969.

Greyson, B., 1993. Varieties of near-death experience. Psychiatry. 56, 390−399.

Greyson, B., 1998. The incidence of near-death experiences. Med. Psychiatry. 1, 92−99.

Greyson, B., 1999. Defining near-death experiences. Mortality. 4 (1), 7−19.

Greyson, B., 2000. Near-death experiences. In: Cardeña, E., et al., (Eds.), Varieties of Anomalous Experiences. American Psychological Association, Washington, DC, pp. 315−352.

Greyson, B., 2003. Incidence and correlates of near-death experiences in a cardiac care unit. Gen. Hosp. Psychiatry. 25 (4), 269−276.

Greyson, B., 2005. "False positive" claims of near-death experiences and "false negative" denials of near-death experiences. Death Stud. 29 (2), 145−155.

Greyson, B., 2007. Consistency of near-death experience accounts over two decades: are reports embellished over time?. Resuscitation. 73 (3), 407−411.

Greyson, B., Bush, N.E., 1992. Distressing near-death experiences. Psychiatry. 55, 95−110.

Greyson, B., Stevenson, I., 1980. The phenomenology of near-death experiences. Am. J. Psychiatry. 137, 1193−1196.

Greyson, B., Fountain, N.B., Derr, L.L., Broshek, D.K., 2014. Out-of-body experiences associated with seizures. Front. Hum. Neurosci. 8 (65).

Grof, S., Halifax, J., 1978. The Human Encounter with Death. Dutton, New York.

Grossman, E.D., Blake, R., 2002. Brain areas active during visual perception of biological motion. Neuron. 35 (6), 1167−1175.

Grosso, M., 1983. Jung, parapsychology, and the near-death experience: toward a transpersonal paradigm. Anabiosis. 3 (1), 4−38.

Groth-Marnat, G., 1994. Cross-cultural perspectives on the near-death experience. Aust. Parapsychol. Rev. 19, 7−11.

Grüsser, O.J., Landis, T., 1991. The splitting of "I" and "me": heautoscopy and related phenomena. In: Grüsser, O.J., Landis, T. (Eds.), Visual Agnosias and Other Disturbances of Visual Perception and Cognition. Macmillan, Amsterdam, pp. 297−303.

Halgren, E., Walter, R., Cherlow, D., Crandall, P., 1978. Mental phenomena evoked by electrical stimulation of the human hippocampal formation and amygdala. Brain. 101 (1), 83−115.

Hänsell, A., Lenggenhagerl, B., Känell, R., Curatolol, M., Blankel, O., 2011. Seeing and identifying with a virtual body decreases pain perception. Eur. J. Pain. 15 (8), 874−879.

Hécaen, H., de Ajuriaguerra, J., 1952. Méconnaissances et hallucinations corporelles: Intégration et désintégration de la somatognosie. Masson, Paris.

Hécaen, H., Green, A., 1957. Sur l'héautoscopie. A propos de quelques cas récents. Encéphale. 46, 581−594.

Heim, A., 1892. Notizen über den Tod durch Absturz. Jahrbuch des Schweizer Alpenklub. 27, 327−337.

Heydrich, L., Blanke, O., 2013. Distinct illusory own-body perceptions caused by damage to posterior insula and extrastriate cortex. Brain. 136 (3), 790−803.

Hoepner, R., Labudda, K., May, T.W., Schoendienst, M., Woermann, F.G., Bien, C.G., et al., 2013. Ictal autoscopic phenomena and near death experiences: a study of five patients with ictal autoscopies. J. Neurol. 260, 742−749. Available from: http://dx.doi.org/10.1007/s00415-012-6689-x.

Hogan, R.E., Kaiboriboon, K., 2003. The "dreamy state": John Hughlings-Jackson's ideas of epilepsy and consciousness. Am. J. Psychiatry. 160 (10), 1740−1747.

Hughlings-Jackson, J., 1888. On a particular variety of epilepsy ("intellectual aura"), one case with symptoms of organic brain disease. Brain. 11 (2), 179–207.
Ionta, S., Heydrich, L., Lenggenhager, B., Mouthon, M., Fornari, E., Chapuis, D., et al., 2011. Multisensory mechanisms in temporo-parietal cortex support self-location and first-person perspective. Neuron. 70 (2), 363–374.
Ionta, S., Martuzzi, R., Salomon, R., Blanke, O., 2014. The brain network reflecting bodily self-consciousness: a functional connectivity study. Soc. Cogn. Affect. Neurosci. 9 (12), 1904–1913.
Irwin, H., 1987. Images of heaven. Parapsychol. Rev. 18, 1–4.
Irwin, H.J., 1985. Flight of Mind: A Psychological Study of the Out-of-Body Experience. Scarecrow Press, Metuchen, NJ.
Irwin, H.J., 1993. The near-death experience as a dissociative phenomenon: an empirical assessment. J. Near Death Stud.
Irwin, H.J., 1999. Near-death experiences. In: Irwin, H.J. (Ed.), An Introduction to Parapsychology, third ed. McFarland, Jefferson, NC, pp. 199–217.
Jansen, K.L.R., 1997. The ketamine model of the near-death experience: a central role for the *N*-methyl-D-aspartate receptor. J. Near Death Stud. 16 (1), 5–26.
Jasper, K., 1913. Über leibhafte Bewusstheiten (Bewusstheitstäuschungen), ein psychopathologisches Elementarsymptom. Z. Pathopsychol. 2, 150–161.
Judson, I.R., Wiltshaw, E., 1983. A near-death experience. Lancet. 322 (8349), 561–562.
Jürgens, T.P., Schulte, L.H., May, A., 2014. Migraine trait symptoms in migraine with and without aura. Neurology. 82, 1416–1424.
Kahane, P., Hoffmann, D., Minotti, L., Berthoz, A., 2003. Reappraisal of the human vestibular cortex by cortical electrical stimulation study. Ann. Neurol. 54 (5), 615–624.
Kelly, E.W., 2001. Near-death experiences with reports of meeting deceased people. Death Stud. 25 (3), 229–249.
Kinney, H.C., Samuels, M.A., 1994. Neuropathology of the persistent vegetative state. A review. J. Neuropathol. Exp. Neurol. 53 (6), 548–558.
Kohr, R.L., 1983. Near-death experiences, altered states, and psi sensitivity. Anabiosis J. Near Death Stud. 3, 157–176.
Lackner, J.R., 1992. Sense of body position in parabolic flighta. Ann. N.Y. Acad. Sci. 656 (1), 329–339.
Lange, R., Greyson, B., Houran, J., 2004. A Rasch scaling validation of a "core" near-death experience. Br. J. Psychol. 95 (2), 161–177.
Lempert, T., Bauer, M., Schmidt, D., 1994. Syncope and near-death experience. Lancet. 344 (8925), 829–830.
Lenggenhager, B., Tadi, T., Metzinger, T., Blanke, O., 2007. Video ergo sum: manipulating bodily self-consciousness. Science. 317 (5841), 1096–1099.
Lhermitte, J., 1951. Visual hallucination of the self. Br. Med. J. 1 (4704), 431.
Lhermitte, J., 1998. L'image de notre corps. Editions L'Harmattan, Paris.
Lippman, C.W., 1953. Hallucinations of physical duality in migraine. J. Nerv. Ment. Dis. 117 (4), 345–350.
Locke, T.P., Shontz, F.C., 1983. Personality correlates of the near-death experience: a preliminary study. J. Am. Soc. Psych. Res. 77, 311–318.
Lopez, C., Blanke, O., 2007. Neuropsychology and neurophysiology of self-consciousness: multisensory and vestibular mechanisms. In: Holderegger, A., et al., (Eds.), Hirnforschung und Menschenbild. Beiträge zur interdisziplinären Verständingung. Academic Press/Schwabe, Fribourg/Basel, pp. 183–206.
Lopez, C., Blanke, O., 2011. The thalamocortical vestibular system in animals and humans. Brain Res. Rev. 67 (1), 119–146.
Lopez, C., Halje, P., Blanke, O., 2008. Body ownership and embodiment: vestibular and multisensory mechanisms. Neurophysiol. Clin. 38 (3), 149–161.
Lopez, U., Forster, A., Annoni, J., Habre, W., Iselin-Chaves, I., 2006. Near-death experience in a boy undergoing uneventful elective surgery under general anesthesia. Pediatr. Anesth. 16 (1), 85–88.
Lundahl, C.R., 1992. Angels in near-death experiences. J. Near Death Stud. 11 (1), 49–56.
Lunn, V., 1970. Autoscopic phenomena. Acta Psychiatr. Scand. 46 (s219), 118–125.
Maillard, L., Vignal, J.P., Anxionnat, R., Taillandier, L., Vespignani, H., 2004. Semiologic value of ictal autoscopy. Epilepsia. 45 (4), 391–394.
Manford, M., Andermann, F., 1998. Complex visual hallucinations. Clinical and neurobiological insights. Brain. 121 (10), 1819–1840.
Menninger-Lerchenthal, E., 1946. Das Truggebilde der eigenen Gestalt (Heautoskopie, Doppelgänger). Kärger, Berlin.
Menz, R.L., 1984. The denial of death and the out-of-the-body experience. J. Relig. Health. 23 (4), 317–329.
Metzinger, T., 2004. Being No One: The Self-Model Theory of Subjectivity. MIT Press, Cambridge, MA.
Metzinger, T., 2005. Out-of-body experiences as the origin of the concept of a "soul". Mind Matter. 3 (1), 57–84.
Mittelstaedt, H., Glasauer, S., 1993. Illusions of verticality in weightlessness. Clin. Investig. 71 (9), 732–739.
Moerman, N., Bonke, B., Oosting, J., 1993. Awareness and recall during general anesthesia: facts and feelings. Anesthesiology. 79 (3), 454–464.
Mohr, C., Blanke, O., Brugger, P., 2006. Perceptual aberrations impair mental own-body transformations. Behav. Neurosci. 120 (3), 528.
Monroe, R.A., 1977. Journeys Out of the Body. Corgi, London.
Moody, R.A., 1977. Reflections on Life After Life. Mockingbird Books, Atlanta.
Moody, R.A., 2001. Life after Life. Mockingbird Books, Covington.
Morgan, W., 2002. Hypnosis in sport and exercise psychology. In: Van Raalte, J.L., Brewer, B.W. (Eds.), Exploring Sport and Exercise Psychology, second ed. American Psychological Association, Washington, DC, pp. 151–181.
Morse, M., Castillo, P., Venecia, D., Milstein, J., Tyler, D.C., 1986. Childhood near-death experiences. Am. J. Dis. Child. 140 (11), 1110–1114.
Moseley, M.E., Cohen, Y., Kucharczyk, J., Mintorovitch, J., Asgari, H. S., Wendland, M.F., et al., 1990. Diffusion-weighted MR imaging of anisotropic water diffusion in cat central nervous system. Radiology. 176 (2), 439–445.
Muldoon, S.J., Carrington, H., 1969. The Phenomena of Astral Projection. Rider & Co., London.
Murray, C., Fox, J., 2005a. The out-of-body experience and body image: differences between experients and nonexperients. J. Nerv. Ment. Dis. 193 (1), 70–72.
Murray, C.D., Fox, J., 2005b. Dissociational body experiences: differences between respondents with and without prior out-of-body-experiences. Br. J. Psychol. 96 (4), 441–456.
Nelson, K.R., Mattingly, M., Lee, S.A., Schmitt, F.A., 2006. Does the arousal system contribute to near death experience? Neurology. 66 (7), 1003–1009.
Nelson, K.R., Mattingly, M., Schmitt, F.A., 2007. Out-of-body experience and arousal. Neurology. 68 (10), 794–795.
Noyes, R., Kletti, R., 1976. Depersonalization in the face of life-threatening danger: a description. Psychiatry. 18, 375–384.
Noyes, R., Slyman, D., 1984. The subjective response to life-threatening danger. In: Greyson, B., Flynn, C. (Eds.), The Near-Death Experience, Problems, Prospects, Perspectives. Charles C. Thomas, Springfield, IL, pp. 17–29.
Noyes Jr., R., Kletti, R., 1977. Depersonalization in response to life-threatening danger. Compr. Psychiatry. 18 (4), 375–384.
Osis, K., Harraldsson, E., 1977. At the Hour of Death. Avon, New York, NY.

Osterman, J.E., Hopper, J., Heran, W.J., Keane, T.M., van der Kolk, B.A., 2001. Awareness under anesthesia and the development of posttraumatic stress disorder? Gen. Hosp. Psychiatry. 23 (4), 198−204.
Overeem, S., Mignot, E., GertvanDijk, J., Lammers, G.J., 2001. Narcolepsy: clinical features, new pathophysiologic insights, and future perspectives. J. Clin. Neurophysiol. 18 (2), 78−105.
Overney, L.S., Arzy, S., Blanke, O., 2009. Deficient mental own-body imagery in a neurological patient with out-of-body experiences due to cannabis use. Cortex. 45 (2), 228−235.
Owens, J., Cook, E.W., Stevenson, I., 1990. Features of "near-death experience" in relation to whether or not patients were near death. Lancet. 336 (8724), 1175−1177.
Palmer, J., 1978. The out-of-body experience: a psychological theory. Parapsychol. Rev. 9 (5), 19−22.
Parnia, S., Waller, D.G., Yeates, R., Fenwick, P., 2001. A qualitative and quantitative study of the incidence, features and aetiology of near death experiences in cardiac arrest survivors. Resuscitation. 48 (2), 149−156.
Parnia, S., Spearpoint, K., de Vos, G., Fenwick, P., Goldberg, D., Yang, J., et al., 2014. AWARE—AWAreness during REsuscitation—a prospective study. Resuscitation.
Pegna, A.J., Qayoom, Z., Gericke, C.A., Landis, T., Seeck, M., 1998. Comprehensive postictal neuropsychology improves focus localization in epilepsy. Eur. Neurol. 40 (4), 207−211.
Pegna, A.J., Caldara-Schnetzer, A.-S., Perrig, S.H., Lazeyras, F., Khateb, A., Landis, T., et al., 2002. Is the right amygdala involved in visuospatial memory? Evidence from MRI volumetric measures. Eur. Neurol. 47 (3), 148−155.
Penfield, W., 1955. The role of the temporal cortex in certain psychical phenomena. J. Ment. Sci. 101, 451−465.
Penfield, W., Jasper, H., 1954. Epilepsy and the Functional Anatomy of the Human Brain. Little, Brown, and Co., Boston, MA.
Persinger, M.A., 1983. Religious and mystical experiences as artifacts of temporal lobe function: a general hypothesis. Percept. Mot. Skills. 57, 1255−1262.
Persinger, M.A., 1994. Near-death experiences: determining the neuroanatomical pathways by experiential patterns and simulation in experimental settings. Healing: Beyond Suffering or Death. Publications MNH, Chabanel, Québec, pp. 277−286.
Petkova, V.I., Ehrsson, H.H., 2008. If I were you: perceptual illusion of body swapping. PloS One. 3 (12), e3832.
Petkova, V.I., Björnsdotter, M., Gentile, G., Jonsson, T., Li, T.-Q., Ehrsson, H.H., 2011. From part-to whole-body ownership in the multisensory brain. Curr. Biol. 21 (13), 1118−1122.
Pfeiffer, C., Lopez, C., Schmutz, V., Duenas, J.A., Martuzzi, R., Blanke, O., 2013. Multisensory origin of the subjective first-person perspective: visual, tactile, and vestibular mechanisms. PLoS One. 8 (4), e61751.
Pfister, O., 1930. Shockdenken und Shock-Phantasien bei Höchster Todesgefahr. Int. Z. Psychoanal. 16, 430−455.
Potts, M., 2002. The evidential value of near-death experiences for belief in life after death. J. Near Death Stud. 20 (4), 233−258.
Ranta, S.O.-V., Laurila, R., Saario, J., Ali-Melkkila, T., Hynynen, M., 1998. Awareness with recall during general anesthesia: incidence and risk factors. Anesth. Analg. 86 (5), 1084−1089.
Ravenhill, T.H., 1913. Some experiences of mountain sickness in the Andes. J. Trop. Med. Hyg. 16, 313−320.
Reynolds, M., Brewin, C.R., 1999. Intrusive memories in depression and posttraumatic stress disorder. Behav. Res. Ther. 37 (3), 201−215.
Ring, K., 1982. Life at death: a scientific investigation of the near-death experience. Conward, McCann & Geoghegan, New York.
Ring, K., 1992. The Omega Project: Near-Death Experiences, UFO Encounters, and Mind at Large. William Morrow & Co.
Ringelstein, E.B., Zunker, P., 1998. Low-flow infarction. In: Ginsberg, M., Bogousslavsky, J. (Eds.), Cerebrovascular Disease: Pathophysiology, Diagnosis and Management, vol. 2. Blackwell Science Inc., Cambridge, MA, pp. 1075−1089.
Roberts, G.A., Owen, J.H., 1988. The near-death experience. Br. J. Psychiatry. 153, 607−617.
Rodin, E.A., 1980. The reality of death experiences: a personal perspective. J. Nerv. Ment. Dis. 168 (5), 259−263.
Rogo, D.S., 1986. Life After Death: The Case for Survival of Bodily Death. Aquarian Press Wellingborough, Northamptonshire.
Röhricht, F., Priebe, S., 1997. Disturbances of body experience in schizophrenic patients. Fortschr. Neurol. Psychiatr. 65 (7), 323−336.
Rosen, D.H., 1975. Suicide survivors: a follow-up study of persons who survived jumping from the Golden Gate and San Francisco-Oakland Bay Bridges. West. J. Med. 122 (4), 289.
Röther, J., de Crespigny, A.J., D'Arceuil, H., Moseley, M.E., 1996. MR detection of cortical spreading depression immediately after focal ischemia in the rat. J. Cereb. Blood Flow Metab. 16 (2), 214−220.
Saavedra-Aguilar, J.C., Gómez-Jeria, J.S., 1989. A neurobiological model for near-death experiences. J. Near Death Stud. 7 (4), 205−222.
Sabom, M., 1982. Recollections of death: a medical investigation. Harper & Row, New York.
Sagan, C., 1980. Broca's Brain: Reflections on the Romance of Science. Random House LLC, New York.
Salomon, R., Lim, M., Pfeiffer, C., Gassert, R., Blanke, O., 2013. Full body illusion is associated with widespread skin temperature reduction. Front. Behav. Neurosci. 7.
Sandin, R.H., 2003. Awareness 1960−2002, explicit recall of events during general anaesthesia. Advances in Modelling and Clinical Application of Intravenous Anaesthesia. Springer, pp. 135−147.
Sandin, R.H., Enlund, G., Samuelsson, P., Lennmarken, C., 2000. Awareness during anaesthesia: a prospective case study. Lancet. 355 (9205), 707−711.
Schomer, D.L., O'Connor, M., Spiers, P., Seeck, M., Mesulam, M., Bear, D., 2000. Temporolimbic epilepsy and behaviour. In: Mesulam, M.M. (Ed.), Principles of Behavioural and Cognitive Neurology, second ed. Oxford University Press, pp. 373−405.
Schwaninger, J., Eisenberg, P.R., Schechtman, K.B., Weiss, A.N., 2002. A prospective analysis of near-death experiences in cardiac arrest patients. J. Near Death Stud. 20 (4), 215−232.
Serdahely, W.J., 1990. Pediatric near-death experiences. J. Near Death Stud. 9 (1), 33−39.
Seth, A.K., Suzuki, K., Critchley, H.D., 2011. An interoceptive predictive coding model of conscious presence. Front. Psychol. 2.
Sheils, D., 1978. A cross-cultural study of beliefs in out-of-the-body experiences, waking and sleeping. J. Soc. Psych. Res. 49, 697−741.
Siegel, R.K., 1977. Hallucinations. Sci. Am. 237, 132−140.
Siegel, R.K., 1980. The psychology of life after death. Am. Psychol. 35 (10), 911.
Smith, B.H., 1960. Vestibular disturbances in epilepsy. Neurology. 10 (5), 465.
Smith, R.P., 1991. The examination of labels?a beginning. J. Near Death Stud. 9 (4), 205−209.
Sours, J.A., 1965. The break-off phenomenon: a precipitant of anxiety in jet aviators. Arch. Gen. Psychiatry. 13 (5), 447−456.
Spitellie, P.H., Holmes, M.A., Domino, K.B., 2002. Awareness during anesthesia. Anesthesiol. Clin. North Am. 20 (3), 555−570.
Stevenson, I., Cook, E.W., 1995. Involuntary memories during severe physical illness or injury. J. Nerv. Ment. Dis. 183 (7), 452−458.
Suzuki, K., Garfinkel, S.N., Critchley, H.D., Seth, A.K., 2013. Multisensory integration across exteroceptive and interoceptive domains modulates self-experience in the rubber-hand illusion. Neuropsychologia. 51 (13), 2909−2917.

Tajadura-Jiménez, A., Tsakiris, M., 2014. Balancing the "inner" and the "outer" self: interoceptive sensitivity modulates self-other boundaries. J. Exp. Psychol. Gen. 143 (2), 736.

Takata, K., Inoue, Y., Hazama, H., Fukuma, E., 1998. Night-time hypnopompic visual hallucinations related to REM sleep disorder. Psychiatry Clin. Neurosci. 52 (2), 207−209.

Tart, C.T., 1971. On Being Stoned: A Psychological Study of Marijuana Intoxication. Science and Behavior Books, Palo Alto, CA.

Terhune, D.B., 2009. The incidence and determinants of visual phenomenology during out-of-body experiences. Cortex. 45 (2), 236−242.

Thonnard, M., Charland-Verville, V., Brédart, S., Dehon, H., Ledoux, D., Laureys, S., et al., 2013. Characteristics of near-death experiences memories as compared to real and imagined events memories. PLoS One. 8.

Tormes, F.R., Guedry Jr., F.E., 1974. Disorientation phenomena in naval helicopter pilots. Aviat. Space Eniron. Med. 46, 387−393.

Trimble, M., Freeman, A., 2006. An investigation of religiosity and the Gastaut−Geschwind syndrome in patients with temporal lobe epilepsy. Epilepsy Behav. 9 (3), 407−414.

Tsakiris, M., 2010. My body in the brain: a neurocognitive model of body-ownership. Neuropsychologia. 48 (3), 703−712.

Twemlow, S.W., Gabbard, G.O., 1984. The influence of demographic/psychological factors and preexisting conditions on the near-death experience. Omega J. Death Dying. 15 (3), 223−235.

Van Lommel, P., van Wees, R., Meyers, V., Elfferich, I., 2001. Near-death experience in survivors of cardiac arrest: a prospective study in the Netherlands. Lancet. 358 (9298), 2039−2045.

Veselis, R.A., Reinsel, R.A., Feshchenko, V.A., Dnistrian, A.M., 2002. A neuroanatomical construct for the amnesic effects of propofol. Anesthesiology. 97 (2), 329−337.

Vignal, J.-P., Maillard, L., McGonigal, A., Chauvel, P., 2007. The dreamy state: hallucinations of autobiographic memory evoked by temporal lobe stimulations and seizures. Brain. 130 (1), 88−99.

Walder, B., Tramèr, M.R., Seeck, M., 2002. Seizure-like phenomena and propofol: a systematic review. Neurology. 58 (9), 1327−1332.

Walker, B.A., Serdahely, W.J., 1990. Historical perspectives on near-death phenomena. J. Near Death Stud. 9 (2), 105−121.

Waxman, S.G., Geschwind, N., 1975. The interictal behavior syndrome of temporal lobe epilepsy. Arch. Gen. Psychiatry. 32 (12), 1580−1586.

Wilkins, L.K., Girard, T.A., Cheyne, J.A., 2011. Ketamine as a primary predictor of out-of-body experiences associated with multiple substance use. Conscious. Cogn. 20 (3), 943−950.

Woerlee, G.M., 2005. Mortal Minds: The Biology of Near Death Experiences. Prometheus Books, Amherst, New York.

Yram, 1972. Practical Astral Projection. Corgi, London, Samuel Weiser. Monroe, R.A. (1974) Journeys Out of the Body.

Zahavi, D., 2005. Subjectivity and Selfhood: Investigating the First-Person Perspective. MIT Press, Cambridge, MA.

Zaleski, C., 1988. Otherworld Journeys: Accounts of Near-Death Experience in Medieval and Modern Times. Oxford University Press.

Zubler, F., Seeck, M., Landis, T., Henry, F., Lazeyras, F., 2003. Contralateral medial temporal lobe damage in right but not left temporal lobe epilepsy: a 1H magnetic resonance spectroscopy study. J. Neurol. Neurosurg. Psychiatry. 74 (9), 1240−1244.

Zutt, J., 1953. Existential orientation; its significance for psychiatry. Nervenarzt. 24 (5), 177.