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There is nothing paranormal about near-death experiences: how neuroscience can explain seeing bright lights, meeting the dead, or being convinced you are one of them

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Approximately 3% of Americans declare to have had a near-death experience [1]. These experiences classically involve the feeling that one's soul has left the body, approaches a bright light and goes to another reality, where love and bliss are all encompassing. Contrary to popular belief, research suggests that there is nothing paranormal about these experiences. Instead, near-death experiences are the manifestation of normal brain function gone awry, during a traumatic, and sometimes harmless, event.

The notion that death represents a new beginning, a passing to an afterlife, where we are reunited with loved ones and live eternally in a utopian paradise, is common across most theological doctrines. The theological case is solidified by the anecdotal reports of people who have encountered near-death experiences. These experiences leave an indelible mark on the individual's life, often reducing any pre-existing fear of death. Such experiences have been observed across cultures and can be found in literature dating back to ancient Greece, but are placed firmly in the contemporary conscience by books, such as Raymond Moody's *Life after Life*, which document many cases of near-death experiences. This and other bestseller books have largely omitted discussion of any physiological basis for these experiences, and instead appear to prefer paranormal explanations over and above scientific enlightenment.

Yet, a handful of scientific studies of near-death experiences do exist. One example is a case study in which a patient with diabetes reported a near-death experience during an episode of hypoglycaemia (too low blood sugar). During this episode, the patient was in a sleep-like state with rapid eye-movement (REM) – a common marker of dreaming and thought to underlie the consolidation of memories, a process that may explain life reviews during near-death experiences (e.g. where the individual re-experiences or relives events from their life). Despite not being in danger of dying, upon resuscitation, the patient recounted many of the classic features of the near-death experience [2]. Indeed, Owen and colleagues reported that 30 out of 58 patients (51.7%) who recounted near-death experiences were not in medical danger, and hence death was not so near [3] (Figure 1).

Basic features of near-death experiences

There are a number of common features across near-death experiences. In one study [2], of those who had had a near-death experience, 50% reported an awareness of being dead, 24% said that they had had an out-of-body experience, 31% remembered moving through a tunnel, and 32% reported meeting with deceased people. Moreover, while it is a common anecdote that near-death experiences are associated with feelings of euphoria and bliss, only 56% associated the experience with such positive emotions, and some even reported negative experiences.

An awareness of being dead

One of the most frequently reported features of near-death experiences is an awareness of being dead [2]. These feelings, however, are not limited to near-death experiences. For example, an intriguing syndrome, which can also help to explain the sensations relating to near-death experiences, is 'Cotard' or 'walking corpse' syndrome. This syndrome was named after the French neurologist Jules Cotard and results in 'le délire de negation' – a feeling that one is dead. McKay and Cipolotti published recently a case report on a 24-year old patient called LU with Cotard delusions [4]. LU repeatedly thought that she was in heaven (although actually in National Hospital, Queen Square, London) and that she might have died of flu. The delusions diminished over a few days and were gone after a week. Anatomically, Cotard syndrome has been associated with the parietal cortex, as well as the prefrontal cortex [5], and has been described following trauma, during advanced stages of typhoid and multiple sclerosis. Still, why delusions such as Cotard syndrome occur is unknown. One explanation is that they may simply be an attempt to make sense of the strange experiences that the patient is having.

Out-of-body experiences

Out-of-body experiences are often described as feelings that one is floating outside of the body and in some cases involve 'autoscopy' or seeing one's body from above. The celebrated Canadian neurosurgeon Wilder Penfield argued that the veridical perception during out-of-body experiences

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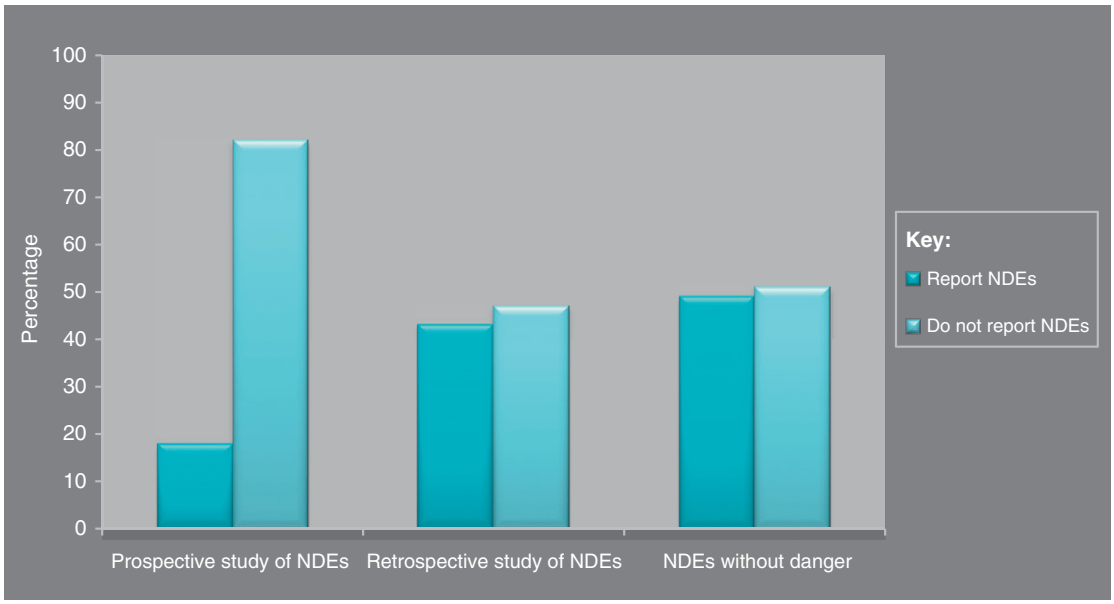

Figure 1. Large scale studies showing the number of people who report near-death experiences (NDEs). The far left bars show that a large proportion (82%) of near-death survivors do not report near-death experiences [2]. The central bars represent a retrospective, or historic, study [15]. Crucially, the far right bars show that around half of the people who reported near-death experiences in this study were not in danger of dying [3].

is brain-based. These experiences are also common during interrupted sleep patterns that occur just prior to sleep or waking. For example, sleep paralysis, which is a natural part of REM sleep and results in paralysis when the person is still aware of the external world, is reported in up to 40% of the population and is associated with hypnagogia (i.e. vivid dreamlike auditory, visual, or tactile hallucinations associated with the wake-sleep cycle), which can result in the sensation of floating above one's body [6]. Recently, Olaf Blanke and colleagues demonstrated that out-of-body experiences can be artificially induced by stimulating the right temporoparietal junction [7]. Upon stimulation, the patient would say things like "I see myself lying in bed…". Other stimulations resulted in the patient feeling as if they were 'floating'. The authors of the study suggested that out-of-body experiences result from a failure to integrate multisensory information from one's body, which results in the disruption of the phenomenological elements of self-representation.

A tunnel of light

Near-death experiences are also associated with the perception that one is moving down a dark tunnel and surfacing into a 'world of light'. These experiences can also be artificially induced: pilots flying at G-force can sometimes experience a phenomenon known as hypotensive syncope, which usually causes tunnel-like peripheral to central visual loss to develop over 5-8 seconds [8]. Although in the case of actual near-death experiences the mechanisms are still unclear, a review by Nelson and colleagues suggested that the light at the end of the tunnel can be explained by visual activity during retinal ischemia [9], which occurs when the blood and oxygen supply to the eye is depleted. A visual disorder, such as glaucoma, can also result in loss of peripheral vision leading to tunnel vision. Indeed, such tunnel vision is associated with extreme fear and hypoxia (i.e. oxygen loss), two processes common to dying. As Blackmore points out, the visual cortex is organized by cells that process peripheral and fovea (i.e. central) vision and excitation of the these cells will result in a central bright light and dark periphery, that is, a tunnel effect [10].

Meeting deceased people

Prevalent in fiction and celluloid is the notion that, when we die, we are surrounded by the souls of the dead, angels or a religious figure in a peaceful transcendental place. Many neuroscientific studies have shown that brain pathology can lead to similar visions. For example, patients with Alzheimer's or progressive Parkinson's disease can have vivid hallucinations of ghosts or even monsters. Patients have also been noted as seeing headless corpses and dead relatives in the house, which has been linked to pallidotomy lesions, suggesting that this result from abnormal dopamine functioning, a neurochemical that can evoke hallucinations[11]. Intriguingly, electrical stimulation of the adjacent region of the angular gyrus can result in a sense of presence (i.e. someone is standing behind us[12]). Macular degeneration (i.e. damage to the center, or macula, of the visual field) can also result in vivid visual hallucinations of ghosts and fairytale characters. Such an example is Charles-Bonnet syndrome, which mostly occurs in the elderly populations. One theory is that hallucinations occur due to compensatory over-activation in brain structures nearby the damaged area or making sense of noise coming from the damaged areas. Thus, hallucinations might be derived from internal sources which are appraised incorrectly.

Positive emotions

Another commonly reported feature of near-death experiences is a feeling of pure bliss, euphoria and an acceptance of death. Many medicinal and recreational drugs, however, can mirror the positive emotions and visions reported in near-death experiences. At varying doses, the administration of ketamine can mimic these experiences including hallucinations, out-of-body experiences, positive emotions such as euphoria, dissociation, and spiritual experiences. Ketamine is sometimes used as an anesthetic through its binding with opioid *mu-* receptors and hallucinations may occur through inhibiting N-methyl-D-aspartate (NMDA) receptors, the same receptors that are evoked during the administration of recreational drugs like amphetamine. Thus, the neurochemical processes that ketamine evokes may be similar to some of the positive emotional experiences and visions during near-death experiences, through evoking the rewarding properties of the opioid system and misattribution of events due to disruption of the prefrontal cortex [13]. Such processes may occur naturally and similar systems are evoked when animals are under extreme danger. For example, dopamine and opioid systems become active when an animal is under predatory attack. Thus, these endogenous systems come into play during highly traumatic events and have likely evolved to aid in the survival of the organism.

Understanding the neurobiological mechanisms of near-death experiences

The near-death experience is a complex set of phenomena and a single account will not capture all its components. One recent theory is that the basic arousal systems beginning in the midbrain may account for many of the components of the near-death experience [10]. Of interest is the locus coeruleus, a midbrain region involved in the release of noradrenaline. Noradrenaline is known to be involved in arousal related to fear, stress, and hypercarbia [10], and is highly connected to regions that mediate emotion and memory, including the amygdala and hippocampus. Indeed, stimulation of the noradrenaline system has been shown to enhance and consolidate memory, and plays a critical role in the sleep-wake cycle, including REM sleep. Along with basic midbrain systems, such as the periaqueductal gray, a region involved in opioid analgesia and basic fear responses, and the ventral tegmental area, which is a core dopamine reward area, the noradrenaline system may be part of a basic set of systems that directly or indirectly evoke positive emotions, hallucinations and other features of the near-death experience.

Taken together, the scientific evidence suggests that all aspects of the near-death experience have a neurophysiological or psychological basis: the vivid pleasure frequently experienced in near-death experiences may be the result of fear-elicited opioid release, while the life review and REM components of the near-death experience could be attributed to the action of the locus coeruleus- noradrenaline system. Out-of-body experiences and feelings of disconnection with the physical body could arise because of a breakdown in multisensory processes, and the bright lights and tunneling could be the result of a peripheral to fovea breakdown of the visual system through oxygen deprivation. *A priori* expectations, where the individual makes sense of the situation by believing they will experience the archetypal near-death experience package, may also play a crucial role [14]. If one challenge of science is to demystify the world, then research should begin to test these and other hypotheses. Only then will discussion of near-death experiences move beyond theological dialogue and into the lawful realm of empirical neurobiology.

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References

1 Schmied, I. *et al.* (1999) Todesnäheerfahrungen in Ost- und Westdeutschland – eine empirische Untersuchung. In *Todesnähe: interdisziplinäre Zugänge zu einem außergewöhnlichen Phänomen* (Knoblaub, H. and Soeffner, H.G., eds), pp. 217–250, Universitätsverlag Konstanz

2 van Lommel, P. *et al.* (2001) Near-Death experiences in surviviors of cardiac arrest: a prospective study in the Netherlands. *Lancet* 358, 2039–2045

3 Owens, J.E. *et al.* (1990) Features of near-death experiences in relation to whether or not the patients were near death. *Lancet* 336, 1175–1177

4 McKay, R. and Cipolotti, L. (2007) Attributional style in a case of Cotard delusion. *Conscious. Cogn.* 16, 349–359

5 Feinberg, T.E. and Keenan, J.P. (2005) Where in the brain is the self? *Conscious. Cogn.* 14, 661–678

6 Cheyne, J.A. and Girard, T.A. (2009) The body unbound: Vestibular-motor hallucinations and out-of-body experiences. *Cortex* 45, 201–215

7 Blanke, O. and Arzy, S. (2004) The out-of-body experience: disturbed self-processing at the temporo-parietal junction. *Neuroscientist* 11, 16–24

8 Lambert, E.H. and Wood, E.H. (1946) Direct determination of man's blood pressure on the human centrifuge during positive acceleration. *Federation Proc.* 5, 59

9 Nelson, K.R. *et al.* (2007) Out-of-body experience and arousal. *Neurology* 68, 794–795

10 Blackmore, S.J. and Troscianko, T. (1988) The Physiology of the Tunnel. *J. Near Death Stud.* 8, 15–28

11 Manford, M. and Andermann, F. (1998) Complex visual hallucinations: Clinical and neurobiological insights. *Brain* 121, 1819–1840

12 Blanke, O. *et al.* (2002) Stimulating illusory own-body perceptions. *Nature* 419, 269–270

13 Liao, Y. *et al.* (2011) Reduced dorsal prefrontal gray matter after chronic ketamine use. *Biol. Psychiatry* 69, 42–48

14 Blackmore, S.J. (1993) *Dying to live: Science and the near-death experience*, Grafton

15 Ring, K. (1980) *Life at death: a scientific investigation of the near-death experience*, Coward McCann and Geoghenan

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