

# Exploration of Near-Death Experience Accounts

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*I dedicate this thesis to  
all the near-death experiencers  
who have shared their experience with our team:  
This work could not have been done without you.*



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## Scientific publications

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The present thesis is based on the following publications:

### *Articles:*

**Cassol, H.**, Bonin, E. A. C., Bastin, C., Puttaert, N., Charland-Verville, V., Laureys, S., & Martial, C. (*in preparation*). Near-death experience memories include more episodic and non-episodic components than flashbulb memories.

**Cassol, H.**, D'Argembeau, A., Charland-Verville, V., Laureys, S.\*, & Martial, C\* (contributed equally). (2019). Memories of near-death experiences: are they self-defining? *Neuroscience of Consciousness*, 5(1), 1-9.

**Cassol, H.**, Martial, C., Annen, J., Martens, G., Charland-Verville, V., Majerus, S., & Laureys, S. (2019). A systematic analysis of distressing near-death experience accounts. *Memory*, 1–8.

**Cassol, H.\***, Martial, C.\* (contributed equally), Charland-Verville, V., Pallavicini, C., Sanz, C., Zamberlan, F., ... Tagliazucchi, E. (2019). Neurochemical models of near-death experiences: A large-scale study based on the semantic similarity of written reports. *Consciousness and Cognition*, 69, 52–69.

**Cassol, H.**, Pétré, B., Degrange, S., Martial, C., Charland-Verville, V., Lallier, F., Bragard, I., Guillaume, M.\*, & Laureys, S\* (contributed equally). (2018). Qualitative thematic analysis of the phenomenology of near-death experiences. *PLOS ONE*, 13(2), 1-14.

### *Book chapter:*

**Cassol, H.**, Martial, M., Charland-Verville, V., & Laureys, S. (*in press*). Les expériences de mort imminente. In A. Dechêne & B. Dupont (Eds.), *Crises* (Methis). Presses Universitaires de Liège.

Other publications related to near-death experiences:

*Articles:*

- Martial, C., **Cassol, H.**, Laureys, S., & Gosseries, O. (*under review*). Near-death experience as a probe to explore (disconnected) consciousness.
- Martial, C., Mensen, A., Charland-Verville, V., Bahri, M. A., Vanhaudenhuyse, A., Rentmeister, D., **Cassol, H.**, Englebert, J., Laureys, S., & Faymonville, M.-E. (2019). Neurophenomenology of near-death experience memory in hypnotic recall: a within-subject EEG study. *Scientific Reports, 9*, 1-11.
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*Book chapters:*

- Charland-Verville, V., Martial, C., **Cassol, H.**, & Laureys, S. (2017). Near-death experiences: Actual considerations. In C. Schnakers & S. Laureys (Eds.), *Coma and Disorders of Consciousness: Second Edition* (pp. 235–263).



## Other publications:

### Articles:

- Aubinet, C., **Cassol, H.**, Gosseries, O., Bahri, M. A., Larroque, S. K., Majerus, S., Martial, C., Martens, G., Carrière, M., Chatelle, C., Laureys, S., & Thibaut, A. (*under review*). Brain metabolism but not grey matter volume underlies the presence of language function in the minimally conscious state.
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- Carrière, M., **Cassol, H.**, Aubinet, C., Panda, R., Thibaut, A., Martial, C., Bahri, M. A., Larroque, S., Chatelle, C., Martens, G., Chennu, S., Laureys, S., & Gosseries, O. (*under review*). Auditory localisation as a sign of consciousness: evidence from clinical, neuroimaging and electrophysiological findings.
- Annen, J., Filippini, M. M., Bonin, E., **Cassol, H.**, Aubinet, C., Carrière, M., Gosseries, O., Thibaut, A., Barra, A., Wolff, A., Sanz, L. R. D., Martial, C., Laureys, S., & Chatelle, C. (2019). Diagnostic accuracy of the CRS-R index in patients with disorders of consciousness. *Brain Injury, 33*(11), 1409–1412.
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Stawarczyk, D., **Cassol, H.**, & D’Argembeau, A. (2013). Phenomenology of future-oriented mind-wandering episodes. *Frontiers in Psychology*, 4(425), 1-12.

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**Cassol, H.\***, Wolff, A.\* (contributed equally), Chatelle, C., Gosseries, O., Laureys, S., & Chatelle, C. (2018). Conscience et états de conscience altérée. In C. Jourdan, F. Pellas, J. Luauté, B. Chevalier, & X. de Boissezon (Eds.), *Etats de Conscience Altérée - Actualités Diagnostiques, Pronostiques et Thérapeutiques*. Sauramps Médical.

Wolff, A., Blandiaux, S., **Cassol, H.**, Chatelle, C., Laureys, S., & Gosseries, O. (2018). Evaluations comportementales chez les patients en état de conscience altérée. In *Etats de Conscience Altérée - Actualités Diagnostiques, Pronostiques et Thérapeutiques*. Sauramps Médical.



# List of abbreviations

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<b>AI</b>	Autobiographical Memory Interview
<b>ANOVA</b>	Analysis Of Variance
<b>CES</b>	Centrality of Event Scale
<b>DES</b>	Dissociative Experience Scale
<b>DMT</b>	<i>N,N</i> -Dimethyltryptamine
<b>EEG</b>	Electroencephalogram
<b>IANDS</b>	International Associations for Near-Death Studies
<b>IQR</b>	Inter-Quartile Range
<b>IVR</b>	Immersive Virtual Reality
<b>LCI-R</b>	Life-Change Inventory - Revised
<b>LSA</b>	Latent Semantic Analysis
<b>MCQ</b>	Memory Characteristics Questionnaire
<b>MoCA</b>	Montreal Cognitive Assessment
<b>NDE</b>	Near-Death Experience
<b>NDE-like</b>	Near-Death-like Experience
<b>NLP</b>	Natural Language Processing
<b>NMDA</b>	N-Methyl-D-Aspartate
<b>OBE</b>	Out-of-Body Experience
<b>PCA</b>	Principal Component Analysis
<b>PTSD</b>	Post-Traumatic Stress Disorder
<b>REM</b>	Rapid-Eye Movement
<b>SD</b>	Standard Deviation
<b>SDM</b>	Self-Defining Memory
<b>SVD</b>	Singular Value Decomposition
<b>WCEI</b>	Weighted Core Experience Index



# Abstract

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After facing a life-threatening situation (e.g., cardiac arrest), or a situation perceived as such, some people will report peculiar life-changing events known as “near-death experiences” (NDEs). These experiences, that typically include transcendental and mystical features (e.g., out-of-body experiences, meeting with deceased relatives), have aroused curiosity among lay people and scientists. To date, the mechanisms that underlie the emergence of the phenomenon and its rich memory remain ill-described. Consequently, by exploring NDE accounts, the aims of this thesis were three-fold: i) to contribute to a better description of the NDE phenomenology; ii) to examine how its memory is stored in autobiographical memory; and iii) to explore its potential neurochemical models.

**Study 1:** By means of an exploratory qualitative thematic analysis, we extracted the common features reported in written NDE accounts. We identified ten “time-bounded” (i.e., isolated features experienced during the NDE) and one “transversal” theme (i.e., a feature that shapes the whole experience and does not correspond to a defined point in time). Time-bounded themes were the following: “light”, “return”, “meeting”, “hyperlucidity”, “description of scenes”, “darkness”, “out-of-body experience”, “awareness of death”, “life events” and “entrance in the NDE”. The “altered time perception” was identified as the only transversal theme.

**Study 2:** NDEs are typically associated with positive affect; however, some distressing NDEs have also been described. Empirical investigations about these phenomena are still lacking. Our goal was therefore to examine their prevalence, content and possible precipitating factors. Results showed that they represent 14% of our sample and that they are as phenomenologically detailed as “classical” NDEs. Besides, they seem to follow suicidal attempts more often. These findings support the possible implication of “top-down” processes in the emergence of NDEs: when sensory inputs are degraded (i.e., altered states of consciousness), the content of the conscious experience produced by our brain could be influenced by one’s state of mind and/or prior knowledge in order to mentally “fill in the gap”.

**Study 3:** Given the reported impact of NDE memories on experiencers’ lives, we assessed to what extent they could meet the definition of “self-defining

memories” (SDMs; i.e., vivid memories that strongly contribute to our sense of self). NDE experiencers described their two main SDMs and completed the Centrality of Event Scale (i.e., to assess how central an event is to one’s identity). The NDE memory was reported by a majority of participants. Moreover, it was considered more “central” compared to other SDMs. Findings confirm the strong impact of NDEs and reveal the importance for clinicians to facilitate their integration within the self.

**Study 4:** Given their emotionality and consequentiality, NDE memories are often compared with flashbulb memories (i.e., a vivid memory of the circumstances in which a surprising piece of news was heard). We therefore examined the phenomenological characteristics, centrality and amount of episodic and non-episodic information provided in verbal recalls of NDE, flashbulb and control autobiographical memories. Analyses revealed that NDE memories comprise more episodic details than control autobiographical and flashbulb memories, and more non-episodic details than flashbulb memories. Besides, flashbulb memories are considered less central, and are associated to a lower intensity of feelings while remembering and a lower personal importance. Overall, even though NDE and flashbulb memories seem to be similar at first glance, our findings highlight that NDE memories are unrivaled and particularly rich in details.

**Study 5:** Several neurochemical models have been suggested to reproduce NDE features in a laboratory setting, notably endorphins, DMT and ketamine. To further investigate potential neurochemical models for NDEs, we assessed the semantic similarity between NDE narratives and thousands of reports linked to the use of 165 psychoactive substances. Analyses indicated that the accounts of experiences under ketamine were the most similar to those associated with NDEs. Altogether, results indicate that ketamine could be used as a safe pharmacological model to study the NDE phenomenology in a laboratory setting.

To conclude, we believe that NDE memories can be regarded as SDMs with flashbulb-like components. Their important impact on experiencers’ lives highlights the importance of developing psychological interventions to foster their integration into their life story, especially since some of them are particularly distressing. Besides, if the neural correlates of NDEs have not been identified yet, research has made significant progress in that direction.



# Résumé

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Suite à une situation potentiellement mortelle (par exemple un arrêt cardiaque), ou perçue comme telle, certaines personnes vont décrire des événements particuliers que l'on nomme « expériences de mort imminente » (EMIs). Ces événements, qui comprennent des caractéristiques transcendantales et mystiques (par exemple, une expérience de sortie du corps ou la rencontre avec des proches décédés), suscitent la curiosité de la population générale et de la communauté scientifique. À ce jour, les mécanismes qui sous-tendent l'apparition du phénomène et la richesse de son souvenir restent néanmoins méconnus. Par conséquent, en explorant les récits d'EMIs, cette thèse avait trois principaux objectifs : i) contribuer à une meilleure description des EMIs ; ii) évaluer comment leur souvenir est stocké en mémoire autobiographique ; et iii) explorer de potentiels modèles neurochimiques.

**Étude 1 :** Au moyen d'une analyse qualitative thématique exploratoire, nous avons extrait les caractéristiques communes aux récits écrits d'EMIs. Nous avons identifié dix thèmes « délimités dans le temps » (i.e., des caractéristiques isolées et distinctes au sein des récits écrits) et un thème « transversal » (i.e., un élément qui façonne toute l'expérience et qui ne correspond pas à un moment précis du récit). Les thèmes délimités dans le temps étaient les suivants: lumière, retour, rencontre, hyper-lucidité, description de scènes, ténèbres, expérience de sortie du corps, conscience de la mort, événements de vie et entrée dans l'EMI. La perception altérée du temps, quant à elle, a été identifiée comme étant le seul thème transversal.

**Étude 2 :** les EMIs sont généralement associées à un affect positif. Toutefois, des EMIs négatives ont également été décrites de façon anecdotique. Les études empiriques portant sur ces phénomènes sont peu nombreuses. Notre objectif était dès lors d'examiner leur prévalence, leur contenu et leurs éventuels facteurs déclencheurs. Les résultats ont montré que les EMIs négatives représentent 14% de notre échantillon et que leur souvenir serait aussi détaillé que celui des EMIs dites « classiques ». En outre, il semblerait qu'elles soient plus souvent consécutives à des tentatives de suicide. Ces résultats corroborent l'implication probable de processus « top-down » dans l'émergence des EMIs : lorsque les informations sensorielles sont dégradées (comme lors d'états de conscience altérée), le contenu de l'expérience consciente produite par notre

cerveau pourrait être influencé par notre état d'esprit et/ou les connaissances préalables que nous possédons sur le monde afin de mentalement « combler le vide ».

**Etude 3 :** Etant donné l'impact des souvenirs d'EMIs sur la vie des expérienceurs, nous avons cherché à déterminer s'ils peuvent être considérés comme des « souvenirs définissant le soi » (SDSs ; i.e., des souvenirs vivaces qui contribuent à définir qui nous sommes). Nous avons demandé à des expérienceurs de décrire leurs deux principaux SDSs et de compléter l'Echelle de Centralité de l'Evenement, destinée à évaluer à quel point un événement est central dans la vie d'un individu. Une majorité des participants a rappelé le souvenir de l'EMI parmi les SDSs. De surcroît, ce souvenir est considéré comme plus « central » par rapport aux autres SDSs. Globalement, nos résultats confirment donc l'impact conséquent que peuvent avoir les EMIs et suggèrent qu'il est crucial que les cliniciens facilitent leur intégration au sein de l'identité des expérienceurs.

**Etude 4 :** Compte tenu de leur caractère émotionnel et de leur impact, les souvenirs d'EMIs ont souvent été comparés aux souvenirs « flashes » (i.e., des souvenirs vivaces d'événements publics marquants). Nous avons dès lors exploré les caractéristiques phénoménologiques, la centralité et la quantité d'informations épisodique et non-épisodique fournies au sein des récits verbaux d'EMIs, d'événements flashes et d'événements autobiographiques contrôlés. Nos analyses ont révélé que les souvenirs d'EMIs comprennent davantage d'informations épisodiques que les autres types de souvenirs, et davantage de détails non-épisodiques que les souvenirs flashes. En outre, les souvenirs flashes sont considérés comme moins centraux et comme ayant une importance personnelle moindre. Globalement, nos résultats confirment que les souvenirs d'EMIs se distinguent des autres souvenirs d'événements marquants en étant particulièrement riches en détails.

**Etude 5 :** plusieurs modèles neurochimiques ont été proposés afin de reproduire des caractéristiques d'EMIs en laboratoire, notamment les endorphines, la DMT et la kétamine. Afin d'étudier ces modèles plus en détail, nous avons évalué la similarité sémantique entre les récits d'EMIs et des milliers de récits liés à l'utilisation de 165 substances psychoactives. Nos analyses ont montré que les expériences vécues sous kétamine étaient les plus ressemblantes du point de vue sémantique. Globalement, ces résultats indiquent que la kétamine pourrait constituer un modèle pharmacologique sûr afin d'étudier la phénoménologie des EMIs.

Pour conclure, nous pensons que les souvenirs d'EMIs peuvent être considérés comme des souvenirs définissant le soi avec des composantes de type « flashes ». Leur impact significatif sur la vie des expérienceurs souligne l'importance de développer des interventions psychologiques afin de favoriser leur intégration dans la vie de ces personnes, d'autant que certaines EMIs sont vécues très négativement. En outre, si les corrélats neuronaux des EMIs n'ont pas encore été formellement identifiés, les recherches ont néanmoins fait un pas important dans cette direction.



# 1 Introduction

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Based on the following publication:

**Cassol, H.,** Martial, M., Charland-Verville, V., & Laureys, S. (*in press*). Les expériences de mort imminente. In A. Dechêne & B. Dupont (Eds.), *Crises* (Methis). Presses Universitaires de Liège.

### 1.1 Description of the phenomenon

I saw my entire life scroll before my eyes. Subsequently, I entered a tunnel that seemed endless. I had the feeling that I would never see the end of it. Then, I perceived a very intense light. At that moment, I realized I was not in my body anymore. This may sound strange, but I had left my body envelope. I met some deceased family members and I travelled through the light. I was “transfigured”. I felt an intense feeling of well-being. On the other side of the light, I have seen absolutely beautiful things, so beautiful that I do not have enough words to describe them. All this was very different from the world we know. However, I probably was not ready for this, I thought of my life, my family and acquaintances, and that is the moment when I came back from the experience.

*Text excerpt of the memory of a cardiac arrest reported by a 62-year-old man four years after the event.*

The invention of the artificial respirator in the 1950s and the improvement of resuscitation techniques enabled survival of conditions that were previously fatal to human beings, leading to longer lifespans and an increasing number of accounts of what is commonly known as “near-death experiences” (NDEs) (Bush, 2002). The expression “near-death experience” refers to a set of perceptions generally occurring to an individual, called “experiencer”, during non-ordinary states of consciousness and following life-threatening situations such as cardiac arrest, intracerebral haemorrhage, traumatic brain injuries, near-drowning or asphyxia (Facco, Agrillo, & Greyson, 2015; Greyson, 2000b). The American psychiatrist Bruce Greyson, a pioneer in the scientific study of the phenomenon, defined these

## Introduction

experiences as “profound psychological events including transcendental and mystical elements, typically occurring to individuals close to death or in situations of intense physical or emotional danger” (2000b, pp. 315-316).

The latest studies have estimated that 4 to 15% of the population would experience a NDE (Greyson, 2003; Knoblauch et al., 2001; Lallier, Pacquelet, Théry-Merland, Lorient, & Hurtaud, 2018; Perera & Belanti, 2005; Schmied et al., 1999). Regarding cardiac arrest survivors, the reported prevalence seems higher and would affect 10 to 23% of this specific population (Greyson, 2003; Schwaninger, Eisenberg, Kenneth, & Weiss, 2002; van Lommel, Van Wees, Meyers, & Elfferich, 2001). As discussed later in this introduction, these experiences have been described for centuries; however, our scientific and technologically sophisticated time allowed us to gather enough accounts depicting this phenomenon, thereby permitting to identify recurrent patterns in the experience *per se* as well as in its aftermath.

Regarding its content, a NDE includes a set of distinguishable elements referred to as “features” (or at a lesser extent “characteristics”<sup>1</sup>) in the specialized literature. Among the frequently reported features, we can cite, in order of frequency of appearance: i) an intense feeling of peace and well-being, ii) the sensation of being separated from one's physical body and of existing outside of it (i.e., a phenomenon known as “out-of-body experience” [OBE]), iii) the vision of a brilliant light (described by experiencers as having a mystical origin and provoking an inexorable attraction), iv) an altered time perception, and v) the entry into an unearthly world (Charland-Verville et al., 2014).

Apart from these peculiar features, the phenomenon distinguishes itself by the nature of its memory, which is particularly vivid, rich in details, and would

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<sup>1</sup> Both terms will be used interchangeably throughout this work.

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include more phenomenological characteristics (e.g., sensory details) than memories of other real and imagined events (Thonnard et al., 2013). Besides, many experiencers report an impression of “hyper-reality” and describe the experience as being “more real than real” (Thonnard et al., 2013). Moreover, the amount of memory details subsequently reported by experiencers is positively associated to the richness<sup>2</sup> of the experience. More precisely, the sensory details (i.e., sounds, smells and tastes), the personal importance and the frequency of reactivation of the NDE in memory seem to vary according to the number of features comprised in the experience (Martial, Charland-Verville, Cassol, Didone, et al., 2017).

Given the particular circumstances of appearance of a NDE and its phenomenological and emotional richness, some authors have stipulated that it could be a key element for identity building (Moore & Greyson, 2017; Thonnard et al., 2013). Indeed, the consolidation of one’s identity is based on a certain amount of main emotional events considered as breaking points in one’s life (Berntsen & Rubin, 2006). These breaking points, or seizures, can be defined as causal agents that could explain the choices and changes in values that follow landmark events (Berntsen & Rubin, 2006).

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<sup>2</sup> In the present work, the *richness* of a near-death experience refers to the number of reported features (e.g., feeling of well-being and peace, vision of a bright light, OBE,...).



### 1.1.1 Near-death experiences throughout centuries

While the scientific studies of NDEs flourished in the 1970s, representations of the phenomenon already existed in much older paintings and writings. Thus, in the 5<sup>th</sup> century, Proclus, neo-Platonic philosopher, described an episode experienced by Cleonymus of Athens that clearly resembles current depictions of NDEs: following a loss of consciousness of a few days, Cleonymus described having left her physical body and having raised above it, therefore becoming able to observe very varied landscapes full of colors from an upper perspective (Proclus, 1970).

In the 13<sup>th</sup> century, the Italian writer Dante Alighieri approached the theme of life after death in his long narrative poem entitled “The Divine Comedy” (**Figure 1**).



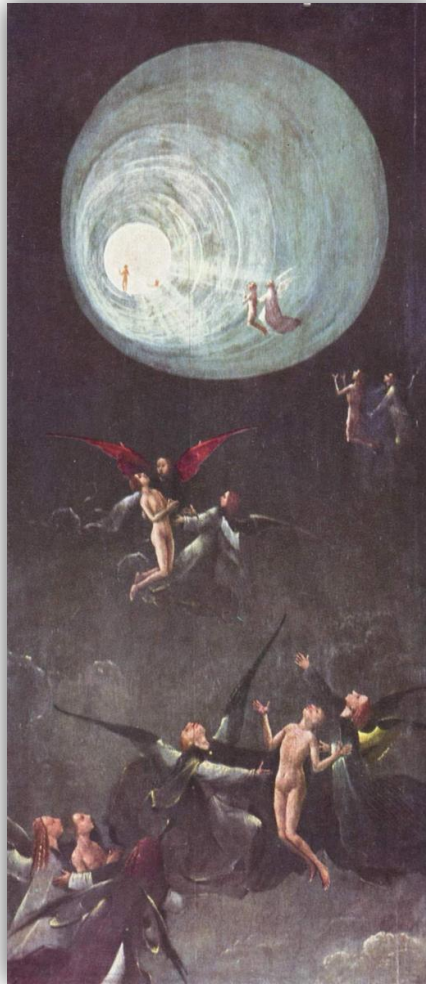
**Figure 1** – Representation of “The Paradise” from Dante Alighieri (engraving created by Gustave Doré in 1868)<sup>3</sup>.

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<sup>3</sup> Image taken from <https://arthistoryproject.com>.

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Later, in the 16<sup>th</sup> century, Hieronymus van Aken, better known as Hieronymus Bosch, painted the seminal four-panel-artwork “Visions of the Hereafter”, which includes “Ascent into the Empyrean”, representing a tunnel and a white light, key features of the NDE (**Figure 2**).



**Figure 2** – Representation of “Ascent into the Empyrean” from Hieronymus Bosch (painted around 1505)<sup>4</sup>.

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<sup>4</sup> Image taken from [https://en.wikipedia.org/wiki/Ascent\\_of\\_the\\_Blessed](https://en.wikipedia.org/wiki/Ascent_of_the_Blessed).

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Around the same time, in his “Essays”, Michel de Montaigne (1582) described an experience of infinite sweetness after a gastrointestinal bleeding. In the following excerpt, he associates the process of dying with a pleasant feeling of peace and an absence of pain:

J’avoy mon estomach pressé de sans caillé... Cependant mon assiette estoit à la vérité très-douce et paisible : je n’avoy affliction ny pour autruy ny pour moy : c’estoit une langueur et une extrême foiblesse, sans aucune douleur Quand on m’eut couché, je senty une infinie douceur à ce repos... On me présenta force remèdes, dequoy je n’en receuz aucun, tenant pour certain que j’estoy blessé à mort par la teste. C’eust esté sans mentir une mort bien heureuse : car la foiblesse de mon discours me gardoit d’en rien juger, et celle du corps d’en rien sentir. Je me lassooy couler si doucement, et d’une façon si molle et si aisée, que je ne sens guere autre action moins poissante que celle-là estoit. Quand je vins à revivre et à reprendre mes forces, qui fut deux ou trois heures après, je me suis senty tout d’un train rengager aux douleurs...

Notwithstanding these various pictorial and written descriptions, it was not until the 19<sup>th</sup> century that the expression “near-death” was formulated for the first time by the Swiss climber and professor of geology Albert von St. Gallen Heim. The expression, that was still informal at the time, was set out by the Swiss mountaineer himself to account for the experience he and his thirty climber teammates went through following an accident in the Alps. It was only in 1891 that Albert von St. Gallen Heim wrote about the peculiar phenomenology and recurring characteristics of these experiences, in the “Annals of the Swiss Alpine Club”. They included an absence of pain, a feeling of infinite calm and peace, an altered time

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perception, auditory perceptions such as music and other sounds, and the vision of idyllic landscapes (Heim, 1891).

This inaugural publication initiated many debates among psychologists and philosophers at the end of 19<sup>th</sup> century and eventually led Victor Egger, French philosopher and epistemologist, to formulate for the first time in French the expression that we are using today “*expérience de mort imminente*”:

We would make a strange dream at the moment of death. While the discourses of the dying are words with the methodical slowness of human thought, in the case of injured people, a sequence of images expresses many more events in much less time. Hence, in a few seconds only, we see many milestones of the past life (personal translation; Egger, 1896).

A few decades later, mainly through the best-seller “Life after Life” written by the American physician and Doctor of Philosophy Raymond Moody (1975), the English expression “near-death experience” was first coined and the NDE phenomenon reached an unprecedented popularity. This publication is noticeable in the sense that it opened the field of contemporary NDE research. In his book, Moody (1975) listed a number of attitudinal changes that may possibly occur following a NDE, such as a decreased fear of death. For numerous experiencers, the NDE is considered a breaking point and a powerful catalyst for change. Moreover, this change is generally perceived as beneficial (Noyes, 1980; Ring, 1984). In addition to the lesser fear of death, various modifications have also been identified, including a perception of increased invulnerability, the feeling of being special and important, a more developed spirituality, a loss of interest in material goods, or an increased compassion towards others (Noyes, 1980; Ring, 1984).

### 1.2 Common features recurring in near-death experiences

Several pioneers in the study of NDEs have analyzed their content and identified the features that characterize the experience. Moody (1975) listed a set of features extracted from a pool of 150 NDE narratives. This list consisted of the following elements: ineffability, the fact that experiencers have heard that they have been pronounced dead, a feeling of peace and tranquility, the sensation of being out of the physical body, hearing noises such as ringing or buzzing sounds, moving through a tunnel, meeting with deceased relatives and/or a being of light, seeing a panoramic playback of one's major life events, approaching a barrier or border representing the limit between earthly life and the next life, and returning to the physical body.

Some years later, Greyson and Stevenson (1980) extracted features from 78 retrospectively collected accounts. The authors found that the characteristics reported were, in order of frequency, a distorted sense of time (79%), OBEs (75%), seeming to enter an unearthly realm (72%), reaching a border or point of no return (57%), having the impression of dying (52%), meeting people that are not physically present (49%), experiencing unusual phenomena such as somatic sensations (e.g., warmth, analgesia) or auditory perceptions (e.g., noise, music: 48%), extrasensory experiences (39%), the impression of passing through a tunnel or a similar structure (31%), and experiencing a life review (27%). In parallel, these authors also looked at the emotional valence associated with the experience and highlighted that a majority described it as neutral or mildly negative (45%). Forty percent of the sample reported a mildly positive experience and 15% a positive one. None of the NDEs were considered as very negative.

Around the same time, Ring (1980) highlighted a set of five core (or main) NDE features consisting of a feeling of peace (60%), an OBE (reported to a lesser

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extent than in previous writings; 37%), entering a tunnel or a dark area (23%), envisioning a light (16%) and entering the light (10%). In addition to these core features, Ring (1980) described other elements such as the decision to return from the experience (57%), the encounter with a presence (41%), the life review (24%), or meeting with deceased relatives (16%). It is not clear, however, how he determined that a feature is (or not) a core component of the phenomenon.

As of today, the key features that are commonly associated with the phenomenon are those listed in the Greyson NDE scale (Greyson, 1983), which is currently the gold standard tool to identify NDEs. Greyson (1983) retained 16 key components: altered time perception, speeded thoughts, feeling of peace, joy, life review, suddenly understanding everything, sense of harmony with the universe, vision of a light, vivid senses, extra-sensory perceptions, pre-cognitions, OBE, unearthly world, encounter with deceased relatives or mystical beings, and coming to a point of no return. Using this scale, some authors have assessed the frequency of these 16 features (Charland-Verville et al., 2014; Greyson, 2003; Parnia, Waller, Yeates, & Fenwick, 2001; Schwartz & Maquet, 2002; Zhi-Ying & Jian-Xun, 1992). **Table 1** sets out the percentages reported in the literature. Overall, the feeling of peace, the brilliant light and the OBE seem to pop out from most studies as the most common manifestations of the phenomenon. Regarding the less common characteristics, they seem to vary according to the study, however, the life review, extrasensory perceptions and precognitive visions appear to be less frequently mentioned (Charland-Verville et al., 2014; Greyson, 2003; Parnia et al., 2001; Schwanager et al., 2002; Zhi-Ying & Jian-Xun, 1992).

If the recurrent features of NDEs have been studied by several authors, their order of appearance in verbal or written narratives remains under-explored. When describing the “core NDE”, Ring (1980) suggested that it consisted of a 5-step sequence that tended to appear in the following order: 1) peace and well-being, 2) separation from the physical body, 3) entry in a dark area, 4) vision of a dazzling

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light, and finally 5) entry through the light into another realm. This 5-step sequence, however, was built upon his personal observations and was not based on any statistical analysis. Consequently, a recent study by our group explored the order of appearance and temporality of NDE features in written narratives (Martial, Cassol, Antonopoulos, Charlier, et al., 2017). We observed that the OBE is often recalled in first position in written accounts and that it is often reported before the feeling of peace and well-being. Besides, “returning into the body” unsurprisingly frequently comes in at last position. The NDE therefore seems to be generally triggered by a sensation of detachment from the physical body and to end with the impression of returning into it. Additionally, we found that the most described sequence of two consecutive features is the “feeling of peace” followed by “encountering with spirits/people”. Finally, the most frequently encountered temporality core features sequence was observed in only six narratives: 1) the OBE, followed by 2) experiencing a tunnel, followed by 3) seeing a bright light, and finally by 4) a feeling of peace. The impossibility of identifying an invariable sequence (i.e., present in all or a majority of accounts) highlights the uniqueness of NDE narratives (Martial, Cassol, et al., 2017).

**Table 1. Frequency (%) of NDE features according to the Greyson NDE scale in the literature.**

	<i>Zhi-ying &amp; Jian-xun,</i> 1992 <i>n=81</i>	<i>Parnia et al.,</i> 2001 <i>n=4</i>	<i>Schwaninger et al.,</i> 2002 <i>n=11</i>	<i>Greyson, 2003</i> <i>n=27</i>	<i>Charland-Verville et al.</i> 2014 <i>n=140</i>
<i>Time distortion</i>	faster=43; slower=20	50 (speeded up)	9	67	75
<i>Thought acceleration</i>	51	NO	9	44	44
<i>Life review</i>	51	NO	9	30	26
<i>Sudden understanding</i>	28	25	18	30	54
<i>Peace</i>	52	75	100	85	91
<i>Joy</i>	10	75	18	67	70
<i>Cosmic unity</i>	16	50	45	52	69
<i>Brilliant light</i>	15	75	63	70	76
<i>Sensory vividness</i>	28	50	54	15	60
<i>Extrasensory perception</i>	14	50	NO	11	34
<i>Precognitive visions</i>	17	NO	9	7	19
<i>Out-of-body experience</i>	43	50	90	70	79
<i>Otherworldly experience</i>	26	50	54	63	72
<i>Mystical presence</i>	12	25	63	26	51
<i>Deceased spirits/religious figures</i>	28	50	72	52	39
<i>Border/point of no return</i>	15	100	45	41	61

NO = Not Observed.



### 1.3 Identification of near-death experiences

The first instrument, the Weighted Core Experience Index (WCEI; **Table 2**), was developed by Ring (1980) based on Moody's (1975) description of a "core experience" (i.e., defined as a consistent experiential pattern that generally unfolds when an individual is seemingly close to death; Ring, 1980). This 10-item scale however left authors with numerous questions relating to the prevalence of the experience as well as the potential influence of the context on its content. In order to provide answers to these remaining questions, Ring and his team administered the WCEI to a sample of 102 persons that had recounted a total of 104 incidents of their close brushes with death. Structured interviews were conducted in this sample that was drawn from a larger group of individuals, of which many members were unwilling to participate. As stated by Ring (1980) himself, however, the sampling was strongly affected by the conditions that led people near death, which is undeniably a cause of bias. More precisely, Ring (1980) reported that accident victims were particularly willing to participate, half of the illness victims gave their consent, and suicide attempters showed the lowest participation rate. Besides, data collection also suffered from a recruitment bias. While illness victims were referred to examiners by medical sources, most suicidal attempters were included following advertisements. Despite all these biases, Ring ultimately determined that nearly half of his sample 48% had lived a core experience based on the index calculated using the ten arbitrarily weighted items of the questionnaire itself.

**Table 2. The Weighted Core Experience Index (WCEI; Ring, 1980).**

Item	Weight
Subjective sense of being dead	1
Feeling of peace, painlessness, pleasantness, etc.	2
Sense of bodily separation	2
Sense of entering a dark region	2
Encountering a presence/ hearing a voice	3
Taking stock of one's life	3
Seeing, or being enveloped in, light	2
Seeing beautiful colors	1
Entering into the light	4
Encountering visible "spirits"	3

For each one of the ten items of the scale, potential experiencers have to answer a yes/no question to indicate if they have experienced the feature. The addition of the ticked items following their respective weight provides an index representing the depth of a NDE. An individual is considered as having lived a "core experience" (i.e., having experienced "enough" components related to this kind of experience) if he/she obtains more than 6 out of 23. In addition, the scale permits to conclude if the experience is "moderate" (score between 6 and 9) or "deep" (score between 10 and 23).

Although Ring's (1980) work is considered as pioneer, his tool however presents substantial limitations. First, the ten items were arbitrarily chosen (i.e., based on his impression of the most often reported features). Second, the cut-off points indicating moderate and deep experiences were not based on statistical analysis and were not tested for internal coherence or reliability. Third, it seems that this scale can lead to false positives when used to identify NDE experiencers (Greyson, 1983).

Given these methodological limitations, Greyson (1983) developed a new scale derived from an initial pool of 80 features described prominently in the NDE

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literature. Based on this exhaustive list, he built a preliminary questionnaire including the 40 most frequent items and launched a pilot study involving 100 participants who had come close to death. On the basis of the collected responses, he eliminated seven items either because of their redundancy or their lack of clarity, and administered the 33-item preliminary questionnaire to a first pool of patients of which 67 responded by referring to 74 distinct experiences (a response rate of 81%). The final scale was composed of 16 items covering four factors based on inter-item correlations and retrospectively designated as “cognitive”, “affective”, “paranormal” and “transcendental”. Items for which item-component and item-scale correlations were deemed acceptable were selected. Regarding answer modalities, respondents have to choose among three options permitting to score each item as being definitely present (corresponding to a score of 2 on the item), atypical or questionable (corresponding to a score of 1 on the item), or absent (corresponding to a score of 0). Based on the answers to the 16 items, a total score ranging from 0 to 32 is calculated, representing the overall intensity of the NDE. Greyson established a cut-off score of 7 or more to consider an experience as a “real” NDE. This cut-off score corresponds to one standard deviation (SD) below the mean of his study sample (i.e., mean=15.01, SD=7.84). To date, the 16-item Greyson NDE scale is the gold standard for a standardized identification of a NDE. It is currently the tool that has the best psychometric qualities. Additionally, Lange, Greyson and Houran (2015) used techniques in computational linguistics to support concurrent validity of the Greyson NDE scale (Greyson, 1983) and confirmed that it identifies a “core experience” that is invariant across age, time since NDE and gender. A detailed description of the scale can be found in **Table 3**.

More recently, a 6-item NDE scale, largely drawn from the Greyson NDE scale has also been developed by Prosnick and Evans (The Near-Death Experience Scale-6; 2003); however, it was practically not used.

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**Table 3. The Greyson near-death experience scale (Greyson, 1983).**

	Item	Possible responses
<b>Cognitive</b>	Did time seem to speed up or slow down?	0 = No 1 = Time seemed to go faster or slower than usual 2 = Everything seemed to be happening at once; or time stopped or lost all meaning
	Were your thoughts speeded up?	0 = No 1 = Faster than usual 2 = Incredibly fast
	Did scenes from your past come back to you?	0 = No 1 = I remembered many past events 2 = My past flashed before me, out of my control
	Did you suddenly seem to understand everything?	0 = No 1 = Everything about myself or others 2 = Everything about the universe
<b>Affective</b>	Did you have a feeling of peace or pleasantness?	0 = No 1 = Relief or calmness 2 = Incredible peace or pleasantness
	Did you have a feeling of joy?	0 = No 1 = Happiness 2 = Incredible joy
	Did you feel a sense of harmony or unity with the universe?	0 = No 1 = I felt no longer in conflict with nature 2 = I felt united or one with the world
	Did you see, or feel surrounded by, a brilliant light?	0 = No 1 = An unusually bright light 2 = A light clearly of mystical or other-worldly origin
<b>Paranormal</b>	Were your senses more vivid than usual?	0 = No 1 = More vivid than usual 2 = Incredibly more vivid
	Did you seem to be aware of things going on elsewhere, as if by extrasensory perception (ESP)?	0 = No 1 = Yes, but the facts have not been checked out 2 = Yes, and the facts have been checked out

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	<p>Did scenes from the future come to you?</p> <p>Did you feel separated from your body?</p>	<p>0 = No 1 = Scenes from my personal future 2 = Scenes from the world's future</p> <p>0 = No 1 = I lost awareness of my body 2 = I clearly left my body and existed outside it</p>
<b>Transcendental</b>	<p>Did you seem to enter some other, unearthly world?</p> <p>Did you seem to encounter a mystical being or presence, or hear an unidentifiable voice?</p> <p>Did you see deceased or religious spirits?</p> <p>Did you come to a border or point of no return?</p>	<p>0 = No 1 = Some unfamiliar and strange place 2 = A clearly mystical or unearthly realm</p> <p>0 = No 1 = I heard a voice I could not identify 2 = I encountered a definite being, or a voice clearly of mystical or unearthly origin</p> <p>0 = No 1 = I sensed their presence 2 = I actually saw them</p> <p>0 = No 1 = I came to a definite conscious decision to "return" to life 2 = I came to a barrier that I was not permitted to cross; or was "sent back" against my will.</p>

### 1.4 Near-death like experiences

Nearly four decades ago, Gabbard, Tremlow and Jones (1981) were already asking: “Do ‘near death experiences’ occur only near death?”. Authors clearly responded in the negative (Gabbard et al., 1981; Gabbard & Twemlow, 1991). Since then, numerous experiences closely resembling NDEs have been described in the scientific literature following various contexts such as syncope (Lempert, Bauer, & Schmidt, 1994), intense grief (Kelly, 2001), and even spontaneously, after an undetermined cause (Facco & Agrillo, 2012). These experiences have been termed “NDEs-like” and are classically described in absence of genuine and/or perceived threat to one’s life (Charland-Verville et al., 2014).

It was originally argued, among the very few publications investigating NDEs-like, that regardless the genuine threat to life, the expectancy of an impending death could be both necessary and sufficient to live a NDE (Gabbard & Twemlow, 1991; Owens, Cook, & Stevenson, 1990). For illustrating purposes, Gabbard and Tremlow (1991) described the case of a marine recruit who accidentally dropped a hand grenade during an instruction session at boot camp and watched the safety pin get out as it hit the ground. This incident, that has proved to be harmless given that the grenade was a dummy, triggered within the young marine an experience regrouping key features of a NDE, such as an OBE, the vision of a light, moving through a tunnel, and an intense feeling of love. As a conclusion, authors suggested that one’s “state of mind” is far more important than one’s “state of the body” in order to experience the phenomenon. Owens, Cook and Stevenson (1990) retrospectively assessed the experiences lived by a sample of 58 patients of whom, based on the analysis of their medical reports, 28 were considered to have been close to death (i.e., they would have died without medical intervention), while the other 30 patients thought they were dying but were actually not in danger. Experiences were similar in both groups of patients; however, patients who were really near death described enhanced perceptions of

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light as well as more cognitive powers (i.e., experiencing enhanced mental and sensory functioning). In another study, Kelly (2001) specifically considered the “encounter with a deceased relative” in a sample of NDE reports consecutive or not to a life-threatening situation (n=237). All participants had lived their NDE as a result of a medical condition, nonetheless, based on the evaluation of medical records, 107 cases were deemed to be “not near death” by two examiners. It is important, however, to note that the author specifies that a few cases were secondary to grief or anxiety, in other words supposedly with no real threat. The exact number of cases might be anecdotal and was not provided.

Considering the studies detailed thus far, one might actually come to the conclusion that the perceived proximity to death –regardless the real danger– is the key element to trigger the phenomenon. In contradiction with this assumption, however, Facco and Agrillo (2012) published the case report of an electrotechnician who experienced an unusual phenomenon with most of the features typical of a NDE except that it happened spontaneously, in absence of any life-threatening conditions, or at least in appearances. This experience, which reached the total score of 16 on the Greyson NDE scale (i.e., thus interpreted as a rich experience), included features such as the vision of a light, intense feelings of peace and joy, the impression of knowing everything about the universe, and the encounter with an entity. Furthermore, an empirical study from Charland-Verville and colleagues (2014) recently examined a relatively large sample (n=50) of NDEs-like. This sample also included experiences that followed a non-life-threatening event with no perceived threats such as, for example, sleep (n=13) or meditation (n=5). Interestingly, authors found that NDE-like experiencers report experiences that are equivalent in content (i.e., the frequency of the characteristics reported by means of the Greyson NDE scale do not differ) and in intensity (i.e., Greyson NDE scale total scores do not differ). Overall, NDEs happening in the aforementioned contexts of occurrence cannot be explained by the perception of an incoming death.

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To conclude, little is known about these experiences. Data regarding their potential causes, their prevalence and their impact on NDE-like experiencers' lives have not been published yet. Although they are still misunderstood, NDEs-like could however be interesting in many aspects, in particular they could make NDEs more empirically accessible by allowing us to recreate experiences that are strongly similar in a controlled environment and without causing a safety hazard to participants. Indeed, previous studies have for example already shown meditation-induced NDE features (Beauregard, Courtemanche, & Paquette, 2009; Van Gordon et al., 2018).



### 1.5 Resulting memory

As mentioned previously, NDEs have fascinated humans since centuries because of their mystical aspect and the surprisingly highly detailed memory that people keep from the event. How is it that experiences supposedly occurring during brain dysfunction lead to such vivid recollections? Despite this intriguing aspect, research on the peculiarity of NDE memories is relatively recent. Most studies have assessed them by means of the Memory Characteristics Questionnaire (MCQ). This questionnaire was developed by Johnson, Foley, Suengas and Raye (1988) in order to more precisely assess the phenomenological characteristics of memories of real and imagined events. When completing this questionnaire, participants are asked to rate the amount of sensory details (i.e., visual, auditory, olfactory and/or gustatory) contained in a memory, the clarity of the representation of the place and time in which the event took place, the clarity of the spatial arrangement of the objects and persons involved in the event, the valence and intensity of the emotional reactions triggered by the event, the memory of the thoughts that the individual had during the event,... Each memory characteristic is assessed on a 7-point Likert scale (e.g., "While remembering the event, I feel as though I am mentally reliving it": 1 = "not at all", 7 = "completely"). In other words, the MCQ enables a more precise examination of the presence of sensory and contextual details (spatio-temporal) during the recall of an event.

In a groundbreaking study using a short 15-item version of the MCQ, Thonnard and collaborators (2013) have highlighted the uniqueness of NDE memories within autobiographical memory (i.e., memories about an individual's life; Williams, Conway, & Cohen, 2008). NDE memories were found to contain more details (e.g., sensory, emotional and self-referential) than memories of other real and imagined events, and memories of a period of coma or impaired consciousness following an acquired severe brain dysfunction without NDE (Thonnard et al.,

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2013). It was therefore suggested that they could not be considered as imagined event memories, but also that they were unique and unrivaled.

Directly inspired by the theoretical premises by Thonnard and collaborators (2013), Palmieri and colleagues (2014) showed that NDE memories were similar to real memories and significantly different from imagined memories in terms of richness, self-referential and emotional information. Besides, they identified specific EEG-patterns in real memories (including NDE memories) as compared to imagined event memories, more precisely higher alpha and gamma bands which are memory-related (Bastiaansen & Hagoort, 2003; Jensen, Kaiser, & Lachaux, 2007). Regarding NDE memories in particular, authors found that they were linked with theta band, known to be a marker of episodic memory, as well as delta band, known to index processes/mental states such as recollections of the past, hallucinations or trance. As a conclusion, authors expressed that NDE memories are not equivalent to imagined ones from a phenomenological point of view. With regard to the neural level, they found that they are stored the same way than memories of other experiences lived in peculiar states of consciousness.

More recently, Moore and Greyson (2017) asked 122 experiencers to rate three memories by means of the 38-item version of the MCQ: i) their NDE memory, ii) the memory of a real event, and iii) the memory of an imagined event (i.e., events they had planned/wished for, dreamed or fantasized about, for example). Overall, MCQ scores for the NDE memories were found to be higher than those of real events memories which, in turn, were higher than those of imagined events.

Finally, we looked into the association between the “richness” of the NDE memory (i.e., which refers to the number of distinct features described, as assessed by the Greyson NDE scale) and the intensity of its phenomenology (as measured by MCQ scores) (Martial, Charland-Verville, Cassol, et al., 2017). We found that Greyson NDE scale and MCQ total scores were positively correlated. In other words, the higher the number of features people experience, the more detailed will

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be the memory. Moreover, authors highlighted that the richness of the NDE memory was particularly associated with the amount of sensory information, the frequency of reactivation and the personal importance.

To conclude, we still do not know how memory consolidation may happen under circumstances in which experiencers are believed to be unconscious and at a moment when memory formation is not expected to operate efficiently. Besides, NDE memories are often reported several decades after the incident but remain very detailed, which led some authors (Martial, Charland-Verville, Cassol, et al., 2017; Thonnard et al., 2013) to compare them with specific autobiographical memories, notably “self-defining memories” (SDMs; i.e., emotional and vivid memories that reflect important themes and conflicts in one’s life; Singer & Salovey, 1993) and “flashbulb memories” (i.e., detailed memories of the circumstances during which a surprising piece of news was heard; Brown & Kulik, 1977).

## 1.6 Characteristics of near-death experiencers

What are the potential factors that could possibly explain that a minority of people will report NDEs while a majority will not? Besides, are there specific individual characteristics that could underlie the emergence of particular NDE features?

### 1.6.1 Age

Most of the scientific literature has been focusing on an adult population; however, NDEs have been reported by people of all ages. For example, even though scientific data is quite scarce, a few authors have described these experiences in children (Atwater, 1996; Bonenfant, 2001; Bush, 1983; Morse, Castillo, Venecia, Milstein, & Tyler, 1986).

Among authors who identified a significant age difference between experiencers and non-experiencers, van Lommel and collaborators (2001) found, in a prospective study, that 52% of their experiencers group were under 60 years of age vs. 34% in the non-experiencers group. In a second prospective study conducted on cardiac arrest survivors, Greyson (2003) also showed that experiencers were younger in average than the comparative group of non-experiencers (56 years old vs. 64 years old, respectively). As raised by Greyson (2003) himself, this age difference might be explained by the fact that younger patients could be more likely to remember them. Indeed, older patients are at higher risks to have reduced blood flow to the brain when experiencing their cardiac arrest and to forget events occurring around that time (Greyson, 2003).

### 1.6.2 Gender

The NDE scientific literature has shown that these experiences have been reported by men as well as women. Specifically, prospective (Greyson, 2003; van Lommel et al., 2001), retrospective (Greyson, 1990; Groth-Marnat & Summers, 1998), and meta-analysis studies involving more than 500 experiencers (Audain, 1999), revealed no significant differences in the proportion of males and females reporting a NDE, suggesting that both groups are equally predisposed to experience, or at least recall, this phenomena.

Other studies have also looked closely at the existing association between the gender and the content of NDEs. Notably, Sabom (1982) found that “encounters/meeting with others” were more frequent in females, and van Lommel and collaborators (2001) pointed out that females experienced “deep” NDEs more frequently than men, as measured by the WCEI (Ring, 1980).

### 1.6.3 Psychopathological characteristics

Neither Gabbard and Twemlow (1984) nor Greyson (1991) have found differences between experiencers and non-experiencers in terms of mental health. On the other hand, even though the underlying processes are little-known, authors have shown that individuals presenting psychiatric disorders tend to describe less elaborate NDEs (e.g., Gabbard & Twemlow, 1984; Greyson, 1991).

One groundbreaking study regarding psychopathological characteristics of experiencers was conducted by Greyson (2000) based on Ring's hypothesis (1992) a few years earlier. Ring (1992) formulated a developmental theory according to which dissociative responses (i.e., a lack of normal integration of thoughts, feelings or experiences into the stream of consciousness and memory; Bernstein & Putnam, 1986) developed during childhood in reaction to a trauma would make some

individuals more prone to live dissociative experiences and/or NDEs later on. Based on this assumption and on the observation that NDEs share some features with the phenomenon of dissociation, Greyson (2000a) compared the amount of dissociative symptoms in people who had lived a NDE following a life-threatening situation and in people who had also lived a life-threatening situation without presenting such an experience. Using the “Dissociative Experiences Scale” (Bernstein & Putnam, 1986), he found that experiencers reported significantly more dissociative symptoms than the other group. Moreover, the depth of the NDE, as measured by the Greyson NDE scale (Greyson, 1983), was positively associated to the quantity of dissociative symptoms. Importantly, however, the amount of dissociative symptoms is lower in experiencers as compared to patients with pathological dissociative disorders. Overall, it was observed that the dissociative symptoms described by experiencers correspond to non-pathological dissociative reactions to stress.

### 1.6.4 Nonpathological characteristics

Nonpathological aspects of human personality have also been analyzed and associated with the NDE phenomenon. Among them, fantasy proneness, defined as a habitual engagement in imaginative activities (Merckelbach, Horselenberg, & Muris, 2001), has received particular attention (e.g., Martial, Cassol, Charland-Verville, Merckelbach, & Laureys, 2018; Ring, 1992). Three decades ago, Ring and Rosing (1990) explored the propensity to imaginary engagement in experiencers by means of the Childhood Experience Inventory (CEI; Holeman, 1994), but failed to show a higher imaginative involvement in comparison to control subjects who had not lived a close brush with death or a NDE. Similarly, Ring (1992) found no tendency to engage in imaginative activities in experiencers, leading Greyson (2000) to conclude that data in favor of fantasy proneness within this population were not compelling. Recently, a study by our group involving 108 experiencers (i.e., 51 who had their NDEs in the

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context of a life-threatening situation and 57 who had lived a NDE-like), showed that participants who reported NDEs-like obtained higher scores of fantasy proneness as compared to those describing classical NDEs, those who did not meet the NDE criteria (i.e., cut-off score of 7 or more at the Greyson NDE scale) and control volunteers. On the contrary, classical experiencers showed a comparable engagement in fantasy than controls. Overall, even though data does not enable us to establish a clear link between fantasy proneness and NDEs, these findings suggest that the important engagement in fantasy in NDE-like experiencers might make them more prone to recall a NDE-like experience when facing suitable conditions such as meditation or syncope. It is important to note that inconsistent observations between studies might be due to the different scales and questionnaires that authors employed to assess fantasy proneness.

In an attempt to identify the psychological correlates of NDEs, Greyson (2003) identified a higher proportion of purportedly psychic experiences (i.e., extrasensory perceptions, paranormal experiences such as *déjà vu*, or altered states of consciousness such as dreams), in experiencers compared to non-experiencers.

Finally, false memory susceptibility was also investigated in a study by Martial, Charland-Verville, Dehon, and Laureys (2017). Authors used the Deese–Roediger–McDermott paradigm (Roediger & McDermott, 1995) to assess susceptibility to create false memories in two groups of participants: i) people who had experienced a NDE following a close brush with death and ii) a group of matched volunteers who underwent a similar life-threatening situation (i.e., comparable etiologies and a period of coma) without recalling a NDE. It turned out that both groups did not differ regarding the susceptibility to recall false memories, but that the recalls in the NDE group were more often accompanied by illusory recollections (i.e., the subjective feeling of remembering that may accompany false recollections).

### 1.6.5 Culture

Most research were conducted in Western cultures (e.g., Charland-Verville et al., 2014; Parnia et al., 2014; Sleutjes, Moreira-Almeida, & Greyson, 2014), however, NDEs have been described by individuals of other origins, notably in China (Zhi-Ying & Jian-Xun, 1992) or India (e.g., Pasricha & Stevenson, 1986). As pointed out by Groth-Marnat (1994), literature in this specific field is difficult to interpret since it usually involves small and varied samples, as well as poor objective means of data collection. In one of the rare studies that have compared narratives from different countries (Belanti, Perera, & Jagadheesan, 2008), authors revealed a number of dissimilarities between Western and non-Western NDEs. For example, Mapuche (i.e., indigenous inhabitants of south-central Chile and southwestern Argentina) and Hawaiian accounts did not comprise features such as the vision of a bright light or a life review, which are deemed common among North American and European experiencers. In addition, overriding characteristics of these reports included descriptions of landscapes made up of volcanoes. Similarities were also detected in Asian accounts originating from Thailand and India, which did not contain depictions of a bright light, tunnels, specific landmarks and encounters with deceased relatives. **Table 4** groups NDE features from different cultures and continents.

### 1.6.6 Religion

NDEs have been reported among individuals belonging to different religions, including Christians of all kinds (Fenwick & Fenwick, 1995; Ring, 1980; Sabom, 1982), Buddhists (Carr, 1993) and Muslims (Suleman, 2004). Furthermore, they also have been described in nonadherents, such as atheists or agnostics (Fenwick & Fenwick, 1995; Ring, 1980; Sabom, 1982). Researchers have found no link between religious (non)affiliation and the content (Sabom, 1982), depth (Ring,



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1980; van Lommel et al., 2001) or incidence of the NDE phenomenon (Ring, 1980; Sabom, 1982; van Lommel et al., 2001).

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**Table 4. NDE features collected in different cultures (adapted from Belanti, Perera, & Jagadheesan, 2008).**

Geographical provenance	Authors	Sample size	Extracted features
<b>Americas</b>			
<i>Hawaii</i>	Kellehear (2001)	1	Deceased people/spirits, visions of landscapes/realms, incorrect time/person, flying
<i>Mapuche</i>	Gómez-Jeria (1993)	1	Deceased people/spirits, visions of landscapes/realms, incorrect time/person, door/gate
<i>Native American</i>	Schorer (1985)	2	Visions of landscapes/realms, out-of-body experiences, animals, color, fire
<b>Africa</b>			
	Morse & Perry (1992)	15	Deceased people/spirits, incorrect time/person, out-of-body experience, highway, stars, negative emotions
<b>Asia</b>			
<i>China</i>	Zhi-Ying & Jian-Xun (1992)	81	Religious figures, evil, deceased people/spirits, visions of landscapes/realms, tunnel, estrangement from the physical body, light, life review, out-of-body experience, sounds, smells, unusual body sensations
<i>India</i>	Pasricha & Stevenson (1986)	16	Religious figures, evil, deceased people/spirits, incorrect time/person, residual marks on one's body
	Pasricha (1993)	13	Deceased people/spirits, incorrect time/person, residual marks on one's body
<i>Israel</i>	Abramovitch (1988)	1	Out-of-body experience, deceased people/spirits, incorrect time/person, light
<i>Thailand</i>	Murphy (2001)	10	Religious figures, evil, deceased people/spirits, incorrect time/person, out-of-body experience, tunnel, hell, animals

**Europe**

<i>Germany</i>	Knoblauch, Schmied, & Schnettler (2001)	82	Heaven, deceased people, door/gate, positive/negative emotions, visions of landscapes/realms, life review
<i>Netherlands</i>	van Lommel et al. (2001)	62	Deceased people/spirits, positive emotions, out-of-body experience, tunnel, light, colors, visions of landscapes/realms, life review

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## 1.6.7 Other

Other demographical variables have been evoked in the NDE literature but studies addressing these are scant. For example, two studies have analyzed the socioeconomic status of experiencers and have compared them to those of non-experiencers. It was notably the case of Ring (1980) who has roughly pre-defined four social-classes categories and found individuals of each subclass in experiencers as well as non-experiencers. Around the same time, Sabom (1982) looked at the size of home community and at the occupation of 78 survivors of near-death crisis, and found no differences between people who had lived NDEs and those who had not.

Finally, although very rarely reported in large-scale studies, the level of education of NDE experiencers has been explored sporadically. The few existing studies found no differences between experiencers and non-experiencers (Groth-Marnat & Summers, 1998; Sabom, 1982), and no relationship between the level of education and the depth or content of the NDE (Sabom, 1982; van Lommel et al., 2001). Besides, no study has yet examined the possible association between the level of education and the aftereffect triggered by NDEs.

### 1.6.8 The specific case of out-of-body experiences

Scientific research has also been focusing on the cognition and personality traits of people who have only experienced OBEs. Irwin (1981, 1985), for example, found that OBE experiencers show greater capacity of absorption (i.e., a disposition in which individuals become absorbed in mental imagery, specifically fantasy; Lynn & Rhue, 1988) than control subjects. More recently, Gow and collaborators (2004) showed that OBE experiencers display a higher propensity to engage in imaginary and fantasy activities by means of the Inventory of Childhood Memories and Imaginings (Wilson & Barber, 1983b), a short form of the Memory, Imagining, and Creativity Schedule (Wilson & Barber, 1983a).

### 1.7 Distressing near-death experiences

Early studies on NDEs reported only very few, if not any, negative experiences (e.g., Moody, 1975; Ring, 1984), leaving them under-explored for many years. Indeed, a substantial majority of NDEs is depicted as pleasant and positive (e.g., Charland-Verville et al., 2014; van Lommel et al., 2001). As highlighted by Charland-Verville and colleagues (2014), for example, the feeling of peace and pleasantness is by far the most frequently reported characteristic as it occurred in 90% of their sample of life-threatening NDEs (i.e., in 89% of anoxic, 93% of traumatic and 91% of other life-threatening NDEs) and 91% of NDEs-like. But what about the other remaining experiences? What exactly do we know about them? As stated by Bush (2002), the hard facts relating to distressing NDEs appear to be as few as the researchers who deal with them.

Even though most studies have identified a proportion of frightening NDEs generally varying between 1 and 10% (e.g., Charland-Verville et al., 2014; Gallup & Proctor, 1982), some authors have found larger proportions of these negative events. For instance, Lindley, Bryan and Conley (1981) collected a total of 55 accounts through calls for NDEs in advertisements and identified 11 (20%) “partially negative or hellish” narratives. Nearly two decades ago, Knoblauch *et al.* (2001) found even greater percentages of distressing NDEs within the German population. The authors compared NDEs experienced in post-socialist East Germany and West Germany, and found out that West Germans experienced more positive NDEs (i.e., 60% described positive emotions and 29% negative ones) compared to East Germans (i.e., 40% of positive emotions and 60% of negative ones). The great disparity in the reported percentages may be explicable, on the one hand, by the use of closed questionnaires which could potentially disguise the presence of negative NDEs (i.e., some distressing experiences also comprise positive emotions) and the Greyson NDE scale only enables the detection of feelings of well-being/peace or joy, therefore, distressing NDEs might be incorrectly identified as

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positive) and, on the other hand, because the frightening and mystical aspects of some experiences could prompt people to withdraw.

In a pioneer study, Greyson and Bush (1992) conducted an investigation on 50 narratives of distressing NDEs. Their qualitative analysis ultimately led to the identification of three subclasses of frightening experiences: (i) the “inverse” experience or “prototypical NDE interpreted as terrifying”; (ii) the experience of “non-existence” or “eternal void”; and (iii) the “hellish” or “demonic” experience. The first subtype shares a lot of features with the classical pleasant NDE (i.e., light, OBE, encounter with deceased relatives, life review...), except that individuals experience very negative feelings such as fear and despair instead of blissful moments. The second-type experience refers to the impression of ceasing to exist or to be condemned to roam through an eternal void forever. This second-type may also include the sensation that life as we know it never existed and is a fraud. Besides, it sometimes comprises features of the classical NDE but at a lesser extent compared to the inverse experience. Finally, experiences with hellish imagery were the less numerous in their sample. These NDEs contain graphic demonic symbolism, like falling into a dark pit or meeting horrific tormented beings. Overall, Greyson and Bush (1992) provide a very vague indication of the frequency of each subcategory in their sample of negative NDEs (i.e., in decreasing order: inverse, void and hellish). Unfortunately, the exact number of accounts belonging to each subcategory is not supplied. In addition to this classification, Rommer (2000) suggested a fourth type during which experiencers are heavily disturbed by a life review, but this category is considered by Bush (2002) as a subtype of hellish NDEs.

Recently, Charland-Verville, Lugo, Jourdan, Donneau and Laureys (2015) found that people suffering from a “locked-in syndrome” (i.e., patients who are conscious but deafferented, and therefore are not able to produce speech and move their limbs/face; Laureys et al., 2005) following an infra-tentorial lesion (i.e., located below the tentorium cerebella) experienced less blissful NDEs compared to

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patients who also went through a period of coma following a supratentorial brain lesion.

Information relating to the impact of frightening NDEs are even more scarce and do not come out from reliable studies. Bush's (2002) personal observations over several years suggest that there are at least three different types of reaction to the making of meaning in distressing NDEs:

- I. **The Turnaround** ("I needed that"): The negative event is perceived as a warning and may lead to a self-analysis and a turnaround in the experiencer's life;
- II. **Reductionism** ("It was only..."): The event is treated as if it did not matter;
- III. **The Long Haul** ("What did I do?"): The frightening event may result in a difficulty to integrate the experience and in the development of a sense of stigma.

As a concluding remark, it is important to stress that frightening NDEs may trigger a post-traumatic stress response (Bush, 2002), symptoms such as recurrent flashbacks (Greyson & Bush, 1992), and long-term reactions like an increased fear of death (Greyson & Bush, 1992). Moreover, they may lead to difficulties in integrating the experience (Flynn, 1986; Greyson, 1997; Noyes, 1980; Ring, 1984; Sabom, 1982). Distressing NDEs are understudied and potentially traumatic, which advocates for further rigorous studies.

## 1.8 Theoretical approaches to near-death experiences

In a very synthetic manner, theoretical approaches to NDEs can be divided into three main categories (e.g., Roe, 2001; Thonnard et al., 2008): i) spiritual (also known as “transcendental” or “dualistic”), ii) psychological, and iii) organic (also referred to as “neurobiological”) theories. This classification is merely used with a view to simplification and clarity. In practice, some of these theories overlap (French, 2009).

### 1.8.1 Spiritual theories: A dualistic perspective

Overall, dualism manifests itself in the idea that our spirit/soul exists independently of our physical body, and in the idea of a life after death (Bloom, 2007; Demertzi et al., 2009). This “dualistic” attitude toward mind-brain relationship appears to be widespread among scholars (Demertzi et al., 2009). Unsurprisingly, many experiencers are similarly convinced that their “soul” separates from their physical body and clearly exists outside of it during their NDE, thereby providing a glimpse into their life after death. This approach towards NDEs is mostly driven by the OBE core feature in particular, during which people observe their physical bodies from an upper perspective and are allegedly able to describe accurately what was going on around them while they were considered “unconscious”.

Advocates of the spiritual theories postulate that NDEs represent a different state of consciousness (i.e., transcendence), in which the self, cognition, and emotions would function independently from the brain (e.g., Parnia, Spearpoint, & Fenwick, 2007; Van Lommel, 2004). For these authors and others, the NDE phenomenon poses a serious challenge to current scientific understandings of the brain, mind and consciousness (Parnia et al., 2001; Ring, 1980; Sabom, 1982). Concomitantly, Ring and Cooper (1999) reported cases of



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blind patients who, after a cardiac arrest, have had an intense OBE of which they could relate elements that would have been verified. Although fascinating, these claims are not supported by any scientific evidence yet. It is currently impossible to determine if these memories actually correspond to an intermediate stage between life and death, or if these would result from a specific neuronal activity. Moreover, no study has yet been able to demonstrate the total absence of cerebral activity during the simultaneous occurrence of a cardiac arrest and a NDE.

In an attempt to elucidate this conundrum, Parnia and collaborators (2014) conducted the AWARE (i.e., AWAreness during REsuscitation) study. Their objectives were twofold: i) investigate the incidence of awareness and the broad range of mental experiences during cardiopulmonary resuscitations, and ii) establish a new methodology to assess the accuracy of reports of awareness as well as visual and auditory perceptions during cardiac arrest. Authors found that two (out of 140) cardiac arrest survivors experienced a NDE including visual awareness of events occurring during their cardiopulmonary resuscitation. Of these two patients, one recalled elements of the environment he/she was in during cardiopulmonary resuscitation that were corroborated by medical records later on. However, the study protocol does not allow excluding that these memories are retrospective imaginative (re)constructions based on the patient's expectations about the world and/or on his/her interactions with the medical staff. Besides, most of the cardiac arrests took place in rooms without shelves, making it impossible to hide targets and verify the claims objectively and in a controlled way. A more refined methodology is therefore needed to provide an objective incidence and to examine information gathered following OBEs associated with critical contexts of impending death.

### 1.8.2 Psychological theories

Some theories rely on the “expectation hypothesis” and take the view that the NDE stems from projections of one’s beliefs regarding an afterlife while being in a life-threatening context and in an altered state of consciousness (e.g., Blackmore & Troscianko, 1989). The plausibility of this hypothesis was discussed by French (2005) who emphasized that religion and spirituality are global human systems of faith and worship that have always existed down the ages. Hence, no culture would be totally free of any form of religious belief and people would keep a form of religiosity deep in their psyche, even in cultures that have abolished any type of creed such as the USSR in the past century. The author however notes that it is quite unclear how individuals who find themselves in life-threatening situations become aware that they are experiencing a close brush with death and develop such complex projections to suit their expectations.

Other psychological theories that focus on more specific aspects have also been suggested. For example, it was hypothesized that NDEs could be the results of a depersonalization or a dissociative phenomenon (i.e., the NDE would be a defense mechanism to evade a distressing reality: when feeling in danger, experiencers would disconnect from their environment to engage in internally generated fantasies; e.g., Noyes & Slymen, 1978). Some authors have also mentioned the potential role of personality factors such as fantasy-proneness, which would make some individuals more prone to exclude frightening elements of their external environment and redirect their attention towards imaginative and sensory experiences (Ring, 1992). False memories were also evoked. Proponents of this hypothesis suggest that at least part of the experience is built by the experience in order to make sense of degraded information during periods of unconsciousness (French, 2001; Mobbs & Watt, 2011).

Finally, Blackmore (1993) made the point that NDEs could be at least partly imagined and would combine information relating to the context of occurrence, elements of one's cultural background, one's prior knowledge, lucky guesses, and degraded information relating to the direct environment that filter through the senses.

### 1.8.3 Organic theories

Organic or neurobiological hypotheses posit that NDEs are produced by the brain. The role of drugs, medication and/or neurotransmitters was notably raised, and various models have been proposed ranging from endogenous opioids to serotonin (Carr & Prendergast, 1981; Morse et al., 1989; Peinkhofer, Dreier, & Kondziella, 2019). Bailey (1973), for example, highlighted the resemblance between trips elicited by drug intakes and the experience of "dying" when describing indigenous societies in North America, notably, who used to ingest peyote (*Lophophora williamsii*, a cactus containing the psychedelic molecule mescaline) during ceremonies to enable a quick overview of what they believed to be their afterlife. It was hypothesized that this association between drugs and the experience of "dying" could be based on their capacity to trigger NDE-like features. Later, Jansen (1990, 1991) discussed the implication of glutamate N-methyl-D-aspartate (NMDA) receptor antagonists in the emergence of NDEs among neurocritical patients, and also suggested a link with hallucinogenic substances such as ketamine. This assumption is based on the high resemblance between the phenomenology of NDEs and the one triggered by the NMDA antagonist ketamine which may induce features such as OBEs, the sensation of entering a tunnel or the vision of a light (Collier, 1972). In critical conditions like hypoxia or temporal lobe epilepsy, which are known to trigger NDEs or NDEs-like, we observe a glutamate flood that overactivates NMDA receptors. This overactivation results in a

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neurotoxicity that substances such as ketamine would hinder. Besides, there are substances that are naturally secreted by the brain and that bind on the same receptors as ketamine does. Therefore, Jansen (1997b) suggested that circumstances that induce a glutamate flood could also produce a flood of neuroprotective compounds binding to NMDA receptors, thereby leading to a specific state of consciousness that displays a phenomenology close to that of recreational ketamine trips. Apart from NMDA antagonists, endorphins were also regarded as being involved in the emergence of some NDE features such as the feeling of peace and well-being (Carr & Prendergast, 1981; Saavedra-Aguilar & Gomez-Jeria, 1989). On the contrary, it was hypothesized that endorphin-blocking agents such as naloxone could generate negatively toned emotions during frightening NDEs (Judson & Wiltshaw, 1983). More recently, our group collaborated in a within-subjects placebo-controlled study aiming at assessing the similarity between the phenomenology induced by the potent serotonergic *N,N*-Dimethyltryptamine (DMT) and NDEs (Timmermann et al., 2018). The injection of DMT in 13 healthy volunteers triggered the emergence of features such as entering an unearthly environment, peace and pleasantness, heightened senses, or a feeling of harmony/unity with the universe. Interestingly, all participants scored above the cut-off score of 7 at the Greyson NDE scale (Greyson, 1983).

Changes in blood gas levels were also studied as a possible cause of NDEs. Acceleration induced loss of consciousness episodes show important similarities with these experiences (Whinnery, 1997). This phenomenon, consisting of a lack of blood flow to the brain (i.e., hypoxia), is sometimes experienced by fighter pilots during maneuvers of important acceleration and may notably provoke tunnel visions, bright lights, OBEs, pleasant sensations and/or visions of beloved ones. Still with regard to hypoxia, Lempert and coworkers (1994) induced syncope in 42 volunteer participants by means of hyperventilation and Valsalva maneuver (i.e., a forced exhalation against a closed airway that is usually performed by closing the mouth and pinching the nose shut while blowing up; Taylor, 1996). Authors found

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out that people reported visual (40%) and auditory (60%) hallucinations, OBEs (16%), feelings of peace and pleasantness (35%), vision of a light (17%), entering another world (47%), encountering preternatural beings (20%), and experiencing a tunnel (8%). Likewise, hypercarbia (i.e., abnormally elevated levels of carbon dioxide in the blood) would induce recollections of past memories/life reviews, visions of a light, OBEs, or mystical experiences (Klemenc-Ketis, Kersnik, & Grmec, 2010; Meduna, 1950).

Other organic causes were suggested as well. Nelson *et al.* (2006), notably, hypothesized that some NDE features (e.g., vision of a light, awareness of being dead) could be a consequence of rapid eye movement (REM; i.e., rapid and random saccadic eye movements, loss of muscle tone, vivid dreams, and cortical activation; Scammell, 2015) intrusions during wakefulness. Indeed, authors found that experiencers described significantly more often REM intrusions than control subjects matched for age and gender. These findings were corroborated by a recent study which showed a higher prevalence of NDEs in people with REM sleep intrusions (Kondziella, Dreier, & Olsen, 2019). Along with REM sleep intrusions, neuronal disinhibition in the visual cortex was also hypothetically envisaged (e.g., Blackmore, 1993; Saavedra-Aguilar & Gomez-Jeria, 1989). Blackmore (1996) suggested that a random excitation in the organization of cells of the visual field might lead to the perception of a bright light and a tunnel vision.

Interestingly, electroencephalography (EEG) studies in humans and rodents seem to indicate a highly coherent electrical activity in the brain just before death. This was first found out in a small human case series by Chawla, Akst, Junker, Jacobs and Seneff (2009), who identified transient electrical spikes in half of their sample of critically ill patients immediately before cardiac arrest. Authors therefore speculated that critical hypoxia entails a cascade of pathological neuronal activity resulting in a transient highfrequency EEG current that fades as neurons lose their resting potential. Interestingly, these findings were later reproduced on a larger

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sample of 35 patients (Chawla et al., 2017). Two studies carried out on rats also described transient increases in electrical brain activity before death (Borjigin et al., 2013; Li et al., 2015). Borjigin and colleagues (2013) detected increased power and global synchronization of gamma oscillations in rats undergoing experimental cardiac arrest. Moreover, directional information transfer across the brain, which is believed to play a role in conscious perception, was characterized by eightfold increase in gamma band in top-down information flow (i.e., believed to be an indicator of consciousness perception) and fivefold increase in bottom-up information processing (i.e., which is thought to be a key element in the treatment of sensory information) at near death. Furthermore, gamma bands were coupled with theta and alpha bands, another key compound of conscious treatment of information in the postarrest brain. Recently, Li *et al.* (2015) demonstrated that induced asphyxia in rats triggered a strong and prolonged surge of functional cortical connectivity as well as an immediate cortical release of various neurotransmitters.

Some researches have considered a dysfunction of the temporal lobe to explain the occurrence of specific NDE features (Blanke, 2005; Blanke, Ortigue, Landis, & Seeck, 2002; Britton & Bootzin, 2004; Hoepner et al., 2013). Indeed, direct cortical stimulation (e.g., Blanke et al., 2002) as well as altered functioning (e.g., caused by brain damage or seizures; Hoepner et al., 2013) of this brain area may trigger OBEs (Britton & Bootzin, 2004) or mystical experiences (e.g., Daly, 1975; Penfield, 1958). For example, it was shown that a deficient multisensory integration due to stimulation of the right temporo-parietal junction in particular leads to OBEs (e.g., De Ridder, Van Laere, Dupont, Menovsky, & Van de Heyning, 2007). This was also found in neurological patients suffering from epilepsy or migraine who have described a similar phenomenology following focal electrical stimulation (e.g., Blanke et al., 2002). These results led authors to hypothesize that hypoxia experienced during life-threatening conditions may hypersensitize neurons as well as lower their seizure thresholds, especially in the temporal lobe that is known to be sensitive to anoxia

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(Benveniste, Drejer, Schousboe, & Diemer, 1984; Britton & Bootzin, 2004; Frenk, McCarty, & Liebeskind, 1978). In accordance with these findings, Britton and Bootzin (2004) detected higher temporal lobe epileptiform activity among NDE experiencers compared to non-experiencers. Interestingly, studies in patients suffering from ecstatic epilepsy (i.e., a type of epileptic seizure resulting in NDEs-like) have also demonstrated the involvement of the anterior insular cortex (Picard & Kurth, 2014; Picard, Scavarda, & Bartolomei, 2013).

In a nutshell, knowing that each aforementioned factor only accounts for a part of the NDE phenomenon, we believe that a combination of several neurophysiological mechanisms may lead to the emergence of a NDE and account for the whole phenomenon. Overall, the causal relationship existing between these numerous factors remains to be determined.

### 1.9 Impact of near-death experiences

It takes very little imagination to conceive that experiences combining such a specific context of appearance (i.e., presumed proximity with death) and phenomenology (i.e., characteristics considered as “paranormal” and/or “transcendental”) may have an impact on experiencers’ lives. The potential aftermath of NDEs indeed stoked researchers’ curiosity since the beginning of their modern-day investigation. One of the first studies focusing on their impact was conducted by Noyes (1980) on a sample of 205 individuals who had come close to death, regardless of what they had subjectively lived; while some of them had experienced a NDE, others had not. Of this relatively large pool, approximately two-thirds described a subsequent change in their attitude towards life and death. The reported pattern of change mainly consisted of a reduced fear of death, a heightened sense of invulnerability, a feeling of being special, important and/or having a special favor from god, and an increased belief in life after death. Later, Ring (1984) developed the Life Change Inventory (LCI), to assess life changing effects after a NDE. When completing this questionnaire, participants are asked to respond in a 5-point likert scale indicating whether and to what degree they have changed regarding different traits and values (i.e., strongly increased (+2), somewhat increased (+1), no change (0), somewhat decreased (-1), and strongly decreased (-2)). Ring (1984) administered his newly created instrument to three groups of individuals: experiencers, people who had come close to death without experiencing a NDE and individuals who had never come close to death. After completion of several interviews, Ring (1984) highlighted that, compared to other groups, experiencers showed a reduced fear of death, were less materialistic, were more sympathetic, and displayed a greater self-confidence, sense of purpose and spirituality (i.e., they tended to turn toward spiritual practices such as prayer or meditation, and at the same time turn away from prior specific religious affiliations and institutions).



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Many subsequent studies have used standardized scales to differentiate experiencers from non-experiencers and assess differences in life changes after life-threatening events by means of a revised version of the Life Change Inventory (i.e., Life Change Inventory - Revised [LCI-R]; Greyson & Ring, 2004). It was found that experiencers systematically reported a greater extent of change compared to non-experiencers (e.g., Ring, 1984; Sutherland, 1992). Groth-Marnath and Summers (1998) also highlighted a correlation of .43 ( $p < .001$ ) between changes emphasized using the Life Change Questionnaire and the total scores at the Greyson NDE scale. This finding could reflect the fact that more intense NDEs (i.e., comprising more typical features) may lead to greater changes, but also that some characteristics specific to each individual, such as their personality traits, could both lead to deeper experiences and foster a greater transformation.

More recently, two other studies were conducted in cardiac arrest survivors. The first of these was carried out by van Lommel and collaborators (2001) who compared, by means of the LCI-R, 35 cardiac arrest survivors who experienced a NDE with 39 who had not. Authors explored the potential changes two and eight years after the cardiac arrest. The two groups differed on 13 of the 34 items of the scale relating to social and religious behaviors, attitude toward death as well as introspection. Details regarding the nature and the magnitude of the changes in the 38 patients for whom data were available at two and eight years can be found in **Table 5**. The second study was conducted by Schwanger and coworkers (2002) and used a comparable design. Similarly, they found greater changes among experiencers, and highlighted that the major modifications related to the religious and spiritual spheres (i.e., greater sense of God's presence, sacredness of life, and purpose in life). Overall, studies on cardiac arrest survivors point towards greater transformative changes in experiencers compared to people who suffered a heart attack without NDE.

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Finally, Barberia, Oliva, Bourdin and Slater (2018) recently performed an original study protocol consisting of immersive virtual reality (IVR) to approach the impact of mortality and NDEs. Healthy volunteers were embodied in alternate virtual avatars on an idyllic island with two companions. They experienced several sessions on the island, starting as a child and progressively ageing. Gradually, participants witnessed the death of the two cronies as well as their own death which comprised the classical features of a NDE (i.e., OBE, life review, the tunnel leading to white light). As compared to a control group, participants subsequently described attitudinal changes similar to those classically reported by real experiencers, notably being more concerned with others and less interested in material issues.

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**Table 5. Sum of individual scores at the Life Change Inventory - Revised per item (n=38; adapted from van Lommel et al., 2001).**

Items	2 years after cardiac arrest		8 years after cardiac arrest	
	NDE group (n=23)	No-NDE group (n=15)	NDE group (n=23)	No-NDE group (n=15)
<i>Social attitude</i>				
Ability to express love for others	42	16	78	58
Acceptance of others	42	16	78	41
Compassion for others	52	25	68	50
Understanding of others	36	8	73	75
Involvement in family life	47	33	78	58
<i>Religious attitude</i>				
Understanding what life is about	52	33	57	66
Sense of inner meaning to my life	52	25	57	25
Concern with spiritual matters	15	-8	42	-41
<i>Attitude toward death</i>				
Fear of death	-47	-16	-63	-41
Conviction there is life after death	36	16	42	16
<i>Others</i>				
Search for personal meaning	52	33	89	66
Interest in self-understanding	58	8	63	58
My appreciation of ordinary things	78	41	84	50

## 1.9.1 Near-death experience as a synonym for “crisis”

### 1.9.1.1 Models of the integration of the near-death experience into one’s personal history

NDEs are often regarded as cornerstones in experiencers’ lives, which has led some authors to reflect upon the integration of the event within their identity. The models developed so far suggest that their aftereffects do not emerge suddenly nor simultaneously, and that the identity transformation that may subsequently occur is not immediately noticeable (Noyes, 1980). Besides, as described by the writer Phyllis Marie Atwater (1988), who experienced a NDE herself, some aspects of the phenomenon may persist over time which could delay its integration. Some people, for example, continue to experience an altered time perception after the NDE.

Sutherland (1992) suggested a progressive change scheme that she called the “integration trajectory”. Concretely, the integration of the event into the experiencer’s identity would begin immediately following the NDE, and then continue until the event becomes an integral part of his/her life. According to the author, there are four types of trajectories (**Table 6**). She suggests that these trajectories are influenced by numerous factors, including the look that the experiencer has on his/her NDE, the perceived control he/she has over the “return to everyday life”, the reaction of their beloved ones to their experience,... The path leading to the integration of the event therefore implies a set of processes in which social acceptance occupies a central place.

**Table 6. NDE integration trajectories proposed by Sutherland (1992).**

<b>Type</b>	<b>Description</b>
<i>Blocked</i>	Specific to experiencers considering the NDE as meaningless
<i>Arrested</i>	Reflects the trajectory of ambivalent experiencers who find it difficult to share the NDE with those around them
<i>Steady</i>	Illustrates a progressive and continuous integration of the experience
<i>Accelerated</i>	Refers to a quick integration of experience

Based on interviews, Hoffman (1995) identified five successive steps in the process of integration of the NDE: i) early shock and surprise, ii) need for validation, iii) interpersonal implications, iv) active exploration, and finally v) integration of the experience into one's personal story. According to Hoffman (1995), communication of the experience at each of these stages would be the keystone of a successful and beneficial integration process.

More recently, Morris and Knafl (2003) also attempted to design a conceptual framework for NDEs, reflecting its meaning for the experiencer. Based on the interviews of 12 experiencers, authors described a first stage that includes a quest for meaning that may result from a feeling of frustration, confusion or depression (i.e., the experiencer questions his mental health). The following step is a growing awareness that authors qualify as "awakening", which is a starting point for new ways of understanding the world around them. This quest for meaning hangs on two major hinges: i) the spiritual domain (i.e., experiencers report a feeling of closeness to a higher entity, increased belief in life after death, less fear of death and developed intuition) and ii) the life course domain (i.e., experiencers perceive their survival as a second chance and reconsider their priorities by placing more emphasis on interpersonal relationships).

### 1.9.1.2 Influencing factors

Noyes, Fenwick and Holden (2009) suggest that several factors are likely to influence the impact of NDEs: i) “pre-NDE factors” that are generally inherent to the individual, such as religious beliefs, culture or personality traits (Ring & Lawrence, 1993), ii) factors linked to the “circumstances and characteristics of the NDE” itself, including its intensity and phenomenological characteristics, and iii) “subsequent factors”, such as the reaction of the experiencer’s relatives to the event.

#### 1.9.1.2.1 Pre-near-death experience factors

As stated above, people who have had a NDE generally report similar changes in values (Noyes, 1980) such as reduced fear of death or a decrease in materialistic interests, however, dissimilarities have also been highlighted. This does not question the fact that there are common consequences on experiencers’ lives, but rather suggests the presence and impact of inter-individual variability among experiencers. Nevertheless, distinguishing between attitudes and behaviors that predated the experience and those resulting from it remains a complex undertaking, especially when it comes to personality traits (i.e., see studies on dissociation and absorption developed earlier in this chapter; e.g., Greyson, 2000a). Moreover, the possible role of some factors remains moot. For example, in the analysis of Western NDEs conducted by Holden, Long and MacLurg (2009), children seem to represent a vulnerable population group given that they do not always have the necessary metacognitive abilities to assimilate what they have experienced. Consequently, they may require special help to understand and integrate the NDE and its consequences.

Other authors have speculated the impact of people’s religious beliefs and culture in the aftereffects of NDEs. Zaleski (1987), for example, brought to light that

experiencers of the Middle Ages described transformative effects compatible with the medieval Christian faith. They reported profound spiritual changes, claimed to be more compassionate and understanding, were no longer afraid of death, and described the acquisition of paranormal abilities. Knoblauch and colleagues (2001) have compared changes in German and American experiencers, and have shown that the decrease in the fear of death was less frequent among the former. Similarly, the development of spirituality seemed less pronounced in this group.

Overall, analyses suggest that pre-NDE factors, such as age, culture or beliefs could influence the content of the experience and how it is assimilated.

### 1.9.1.2.2 Circumstances and characteristics of the experience

Most authors have concentrated on the possible role of specific NDE features. By retrospectively exploring the phenomenology of 78 accounts, Greyson and Stevenson (1980) pointed out that behavioral changes that follow a NDE are more important in experiencers who were aware that they were dying during their NDE as well as among those who reported a life review. Later, Kellehear (1991) suggested that temporary immersion into an unearthly world, and the vision of idyllic landscapes in particular, would incite experiencers to modify their social values as well as their way of life. The entrance into a transcendental and utopian society could induce in experiencers a less sibylline discourse about death. Around the same time, Morse and Perry (1992) speculated that the mystical and transcendental aspect of NDEs, such as the encounter with a cosmic or divine force, could be the reason for the spiritual transformation in many experiencers.

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Finally, we could also hypothesize that the emotional valence of a NDE may have an impact on people's integration of the experience. It is reasonable to think that more frightening NDEs could generate an important stress, and could therefore trigger a crisis more difficult to overcome for the experiencer. Key episodes in one's life have an impact on how one will perceive and interpret future events. When highly negative experiences, such as hellish NDEs, are not integrated appropriately into one's identity (i.e., he/she has not been able to draw a lesson and/or step back from the event), it may have an adverse effect on expectations related to future experiences and, as a result, it may be detrimental to one's mental health (Berntsen, Willert, & Rubin, 2003).



### 1.9.1.2.3 Subsequent factors

In order to study the reciprocal interaction between NDEs and interindividual relationships, Insinger (1991) collected the narratives of 11 experiencers and found that relationships within the family are very likely to evolve. While a majority of families accepted the changes in their beloved ones' values and supported them in their approach, others needed an initial adjustment to understand the NDE and its implications. Some fewer experiencers, however, underwent less approving situations. For example, some of them found that their beloved ones were frustrated with various aspects of their new personality, were sometimes reluctant to discuss about the NDE, or criticized their new life concerns, in particular the loss of interest in material assets. As underlined by the author, it is understandable that a social system, such as family or relatives, endure difficult adjustments while its previous roles and standards undergo more or less significant changes. The most difficult adaptations being the ones in which the family shows an attitude of rejection regarding the experiencer's new system of values.

Similarly, Christian (2005) and Sutherland (1992) described a significant number of divorces triggered by the mismatch between the experiencer's new values and those of his/her partner.

### 1.9.1.3 Near-death experiences as a form of statutory transition

In an innovatory analysis, Glaser and Strauss (1971) presented NDEs under an original angle: they considered the phenomenon as a type of "statutory transition". The authors define the statutory transition as a set of transitional social processes marking the changeover from one status to another. This shift usually

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involves a change in identity and behavior. The transition from one social, religious or wage class to another, such as the passage from childhood to adulthood for example, generates movements within one's social structure. All these changes involve the following successive phases: (1) a separation from the former status, (2) a transitional reorientation period, (3) and an integration and recognition of the new status. According to these two authors (Glaser & Strauss, 1965, 1968), death, as well as the process of dying, can be seen as a statutory transition with its specific characteristics:

- I. Death is usually unexpected;
- II. When it occurs, it is usually defined as an unwanted and unintended event;
- III. Signs of an individual's death are not always clear, both for the caregiver as well as for the dying person;
- IV. The control that the dying person and his/her relatives have over this transition is uncertain and problematic;
- V. The dying person's path may include phases of recovery and relapses that will mark his/her state of mind throughout the process.

Kellehear (1990) extends this thinking to the NDE phenomenon. As the author points out, these two events share common characteristics. Like death, NDEs encompass the following characteristics:

- I. Unpredictability;
- II. Its context of occurrence is often perceived as unintentional and undesired;
- III. Signs of death are not always clear to the individual (e.g., the case of a person suffering a cardiac arrest but who nevertheless presents a NDE, and therefore a content of conscience – perceptions and thoughts);
- IV. The difficulty of gauging the control exercised over a NDE: the impact of this (lack of) control relies on a variety of idiosyncratic factors such as one's perception of physiological (i.e., possible relapse/reoccurrence of the NDE) or

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relational (e.g., one's ease to share the experience with the medical staff) variables. Furthermore, it has been suggested that experiencers themselves could exercise some control over their NDE (i.e., albeit questionable, many of them recounted their conscious decision to "come back" during the experience, especially since they felt that "it was not the right time to let go").

Through his analysis, Kellehear (1990) distinguishes NDEs from other statutory transitions that reflect well-established passages within our social structures. The author describes NDEs as phenomena that are beyond the control and regulation system of our society. Moreover they engender unprecedented changes in values and identity.

### 1.10 Overview of the present work

The aims of the present thesis are three-fold: i) to contribute to a better description of the NDE phenomenology (**chapter 2: study 1 and study 2**); ii) to examine how its memory is stored in autobiographical memory (**chapter 3: study 3 and study 4**); and iii) to explore some of its potential neurochemical models (**chapter 4: study 5**). These objectives will be addressed primarily through the analysis of NDE written accounts.

NDE features have been studied extensively a few decades ago (Greyson & Stevenson, 1980; Greyson, 1983; Ring, 1980; Sabom, 1982). Ever since, however, these experiences came out of the taboo atmosphere, leading to a growing body of descriptions that differed from the initial prototypical NDE. Consequently, **study 1** is exploratory and aims to reach an updated description of the phenomenon by means of a rigorous qualitative thematic analysis, a method that promotes the classification of the data into themes. The aim of **study 2** is to address the lack of empirical data relating to distressing NDEs (Bonenfant, 2001; Greyson & Bush, 1992). To do so, we will look for the proportion of distressing experiences in a large sample of NDEs, analyze their content and further explore their context of occurrence. Although this study is essentially exploratory, we hypothesize that distressing NDEs are as phenomenologically detailed as “classical” ones and that they emerge more frequently following suicidal attempts (i.e., we assume that the psychopathological context surrounding a suicidal attempt may have an influence on the valence of the experience). In **study 3** and **study 4**, we will test the assumptions of Martial, Charland-Verville, Cassol, *et al.* (2017) and Thonnard *et al.* (2013) according to which NDE memories could meet the definition of SDMs and flashbulb recollections, respectively. Given their high emotionality and consequentiality, we hypothesize that NDEs are self-defining and that they are at least as vivid and detailed as flashbulb memories. **Study 5** rather focuses on potential neurochemical models to study NDEs. Indeed, “classical” NDEs are

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impossible to predict, rendering simultaneous brain monitoring impractical. To bypass this issue, models involving several neurotransmitters and drugs were suggested to reproduce NDE features in a laboratory setting, notably DMT and ketamine (e.g., Jansen, 1997b; Timmermann et al., 2018). Therefore, we will explore the semantic similarity between NDE narratives and thousands of written accounts linked to the use of 165 psychoactive substances. Finally, we will conclude the present thesis by discussing our results and the perspective they might bring.



## 2 Exploring the content of pleasant and distressing near-death experiences

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*Based on the following publications:*

**Cassol, H.\***, Pétré, B.\* (contributed equally), Degrange, S., Martial, C., Charland-Verville, V., Lallier, F., Bragard, I., Guillaume, M.\*, & Laureys, S.\* (contributed equally). (2018). Qualitative thematic analysis of the phenomenology of near-death experiences. *PLOS ONE*, *13*(2), 1-14.

**Cassol, H.**, Martial, C., Annen, J., Martens, G., Charland-Verville, V., Majerus, S., & Laureys, S. (2019). A systematic analysis of distressing near-death experience accounts. *Memory*, 1-8.

## 2.1 Study 1. Thematic analysis of near-death experiences accounts

### 2.1.1 Summary

NDEs refer to profound psychological events that can have an important impact on the NDE experiencers' lives. Previous studies have shown that NDEs memories are phenomenologically rich. In the present study, we therefore aimed to extract the common themes (referred to as "features" in the NDE literature) reported by NDE experiencers by analyzing all the concepts stored in the narratives of their experiences. A qualitative thematic analysis has been carried out on 34 cardiac arrest survivors' NDE narratives. Our results shed the light on the structure of the narratives by identifying ten "time-bounded" themes which refer to isolated events encountered during the NDE and one "transversal" theme which characterizes the whole narrative and generally appears as a retrospective comment of self-reflection on the experience. The division of narratives into themes provides us with detailed information about the vocabulary used by NDE experiencers to describe their experience. This established thematic method enables a rigorous description of the phenomenon, ensuring the inclusion of all self-reported manifestations of themes in narratives.



## 2.1.2 Introduction

Despite the significant number of people who reported to have had a NDE, there is still no theory that may account for all the characteristics classically described. Moreover, although it is now widely admitted that this experience is a physiological and psychological reality, a commonly accepted definition of the phenomenon is still lacking. Indeed, NDEs were initially named so because of their connection with death or fear of death (Owens et al., 1990). More recently, however, similar experiences were reported in the absence of a physical or emotional threat (i.e., NDE-like experiences). Charland-Verville and collaborators (2014) have shown that scores of NDE intensity (using self-reported responses on the Greyson NDE scale; Greyson, 1983) do not differ between “real NDEs” experienced after a coma and “NDE-like” experiences occurring after non-life threatening events. Further systematic investigation is therefore required to better characterize these experiences and better describe their phenomenology.

Although a few studies have conducted text analysis on NDEs narratives (Hou, Huang, Prakash, & Chaudhury, 2013; Lange et al., 2015), reports of cardiac arrest survivors have never been, to our knowledge, analyzed using a rigorous qualitative thematic method. Thematic analysis is a method for identifying, analyzing and reporting patterns within data (Braun & Clarke, 2006) commonly used in qualitative research (Pope & Mays, 2006). This method promotes the classification of the data into thematic categories as well as the examination of all the cases in the study to make sure that all the manifestations of each theme have been accounted for and compared (Pope & Mays, 2006). Themes are patterns across data sets that are essential to a better description of a phenomenon. Therefore, thematic analysis can be used to develop taxonomies or classifications about a phenomenon (Pope & Mays, 2006). Furthermore, well-established guidelines for applying and assessing qualitative methods are nowadays available (Malterud, 2001; Tong, Sainsbury, & Craig, 2007), which have increased their use in

## Study 1. Thematic analysis of near-death experiences accounts

medical disciplines (Mays & Pope, 2000). The description of a NDE using closed scales can result in the overlooking of relevant features that might have been experienced by NDE experiencers but that are not listed in NDE questionnaires. Therefore, this study aims to explore the interest of a qualitative approach, specifically thematic analysis, to better portray NDEs that follow a cardiac arrest based on self-reported narratives.

## 2.1.3 Materials and methods

### 2.1.3.1 Sample and recruitment

The study was approved by the ethics committee of the Faculty of Medicine of the University of Liège. NDE experiencers were recruited via the websites, the appearances in local media and the publications of the International Association for Near-Death Studies (IANDS France) and the Coma Science Group (GIGA Research Center, University and University Hospital of Liège, Belgium). Participants who contacted us indicated their consent by signing a written consent form. They then completed questionnaires requesting socio-demographic information (gender and age at interview), their age when they experienced the NDE, the time elapsed since the NDE and if the NDE has occurred during a life threatening event. In addition to these questions, participants were asked to write a detailed narrative of their experience. No limits regarding the number of pages were specified. The Greyson NDE scale (Greyson, 1983) was then used to identify the presence of a NDE. This 16-item multiple-choice validated scale (Greyson, 1983; Lange et al., 2004) allows the quantification of the intensity of the experience (i.e., total score ranging from 0 to 32) and enables a standardized identification of NDEs (i.e., cut-off score of 7). For each of the 16 items, the scores are arranged on an ordinal scale ranging from 0 to 2 (i.e., 0 = “not present”, 1 = “mildly or ambiguously present”, and 2 = “definitively present”; Greyson, 1983; Lange et al., 2004). These 16 items fall into four subscales (i.e., affective, cognitive, paranormal and transcendental components). NDEs being frequently reported after cardiac arrests, we included participants whose experience was secondary to a cardiac arrest and who met the accepted criteria of a NDE (i.e., Greyson NDE scale's total score  $\geq 7$ ; Greyson, 1983). **Table 7** shows the descriptive data of the study sample calculated using SAS version 9.3 for Windows statistical package.

**Table 7. Greyson NDE scale total scores and descriptive data of the 34 NDE experiencers (34 cardiac arrests; 11 females).**

<b>Greyson NDE scale total score</b>	
Mean ± SD	13±5
Range	7–22
<b>Reported time since NDE (in years)*</b>	
Median	6
Interquartile range (IQR)	4–10
<b>Age at NDE (in years)</b>	
Mean ± SD	49±13
Range	16–72
<b>Age at interview (in years)</b>	
Mean ± SD	56±12
Range	18–75

\*This variable being not normally distributed, we used the median and the IQR.

### 2.1.3.2 Thematic analysis

According to the recommendations required for this method (Braun & Clarke, 2006; Miles & Huberman, 1994), an iterative step-by-step thematic analysis has been carried out on all anonymized 34 NDE narratives using NVivo software (version 9.2 for Windows). An inductive proceeding was chosen to analyze the data: themes were inductively defined from the raw data that were explored without any predetermined classification.

In the first step, two expert researchers in thematic analysis (SD and BP) read the narratives several times in order to familiarise themselves with the information. In the second step, emergent themes were developed following a series of coding stages: first, open coding was used and initial codes were

## Study 1. Thematic analysis of near-death experiences accounts

generated. Next, initial codes were grouped into categories according to their similarities. In the third step, these categories were organized into themes. It involves combining codes into overarching themes that accurately depict the data. According to Braun and Clarke (2006) “a theme captures something important about the data and represents some level of patterned response or meaning within the data set”. This work led to a first analysis grid (i.e., list of themes). In the fourth step, both experts independently extracted and classified all quotations (i.e., phrases or paragraphs) that corresponded to a theme of the analysis grid and preserved the quality of the writings as produced. To ensure the reliability of the coding and classification process, coding comparison query that enables to compare coding done by two experts in Nvivo, was performed by calculating a Cohen's kappa coefficient. The kappa coefficient can range from -1 to +1 (+1 corresponding to a perfect concordance between the two experts). In the first instance, readers obtained a Cohen's kappa coefficient of 0.46 demonstrating a moderate agreement (Landis & Koch, 1977). That relatively poor result forced them to revise the analysis grid. According to the criteria of univocality and exclusivity (i.e., to ensure that themes are understandable in the same way by anyone and that quotations can be classified only in one single category), a new arrangement and a more precise definition of the themes have been proposed. Based on the revised grid (see **Table 8**), a new extraction and classification of quotations was achieved and led to a Cohen's kappa coefficient of 0.73 between both readers corresponding to a substantial agreement (Landis & Koch, 1977). The fifth step was made of a comprehensive analysis to examine the extent to which the themes contributed to an understanding of the data. For each theme, all the included quotations were synthesized to bring out the main ideas (i.e., a summary of the content provided by the participants). The sixth step involved writing the report and led to a detailed description of the results. To ensure robustness, descriptive results were accompanied by quotations that illustrate that description. In addition, the number of NDE experiencers who discussed the theme and its different

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characteristics was reported in order to summarize the results in a more illustrative and comprehensive form. A native English speaker translated the quotations included in the present article from French to English in order to preserve the NDE experiencers' subjective points of view.

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**Table 8. Coding structure of NDE narratives.**

<p><b><i>Time-bounded themes</i></b></p>	<p><i>Light</i>: experiences in which the light is the main object.</p> <p>Associated subthemes:</p> <ul style="list-style-type: none"> <li>- Attractiveness</li> <li>- Description of the light</li> <li>- Source of light</li> <li>- Body sensation</li> <li>- Emotional feeling</li> </ul>
	<p><i>Return</i>: transition between the "NDE" and "everyday life".</p> <p>Associated subthemes:</p> <ul style="list-style-type: none"> <li>- Opposition well-being/suffering</li> <li>- Attempt to relive the experience</li> <li>- No explanation</li> <li>- Order to come back</li> </ul>
	<p><i>Meeting/encounter</i>: experience of an individual who encounters other beings (human or imaginary).</p> <p>Associated subthemes:</p> <ul style="list-style-type: none"> <li>- Focus on the bright environment around him/her or bright being</li> <li>- Message- content of the interaction</li> <li>- Typology of being met</li> <li>- Type of interaction</li> <li>- Body sensation</li> <li>- Emotional feeling</li> </ul>
	<p><i>Hyperlucidity</i>: experience of omnipotence and extreme lucidity of the individual.</p> <p>Associated subthemes:</p> <ul style="list-style-type: none"> <li>- Outstanding intelligence, genius</li> <li>- Physical liberation</li> <li>- Links-unification-entirety-infinity</li> <li>- Omnipotence</li> <li>- Body sensation</li> <li>- Emotional feeling</li> </ul>
	<p><i>Description of scenes</i>: experience of an individual describing the scene in which he is immersed.</p> <p>Associated subthemes:</p> <ul style="list-style-type: none"> <li>- Description of the place</li> </ul>

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	<ul style="list-style-type: none"> <li>- Indescribable character of the place</li> <li>- Feeling of infinity</li> <li>- Body sensation</li> <li>- Emotional feeling</li> </ul>
	<p><i>Darkness:</i> experience of an individual describing a dark, black, and deadly environment.</p> <p>Associated subthemes:</p> <ul style="list-style-type: none"> <li>- Description of the dark or black place</li> <li>- Contrast, black/light sequence</li> <li>- Person's movement/environment or lack of movement</li> <li>- Sensory perception</li> <li>- Body sensation</li> <li>- Emotional feeling</li> </ul>
	<p><i>Out-of-body experience:</i> experience of an individual who sees himself in an emergency situation from an observer's perspective.</p> <p>Associated subthemes:</p> <ul style="list-style-type: none"> <li>- Awareness of being out of the body (state)</li> <li>- Experience of de-corporation (action of, way of getting out)</li> <li>- Visual description of the actual situation</li> <li>- High position, over flight</li> <li>- Attempt to communicate</li> <li>- Body sensation</li> <li>- Emotional feeling</li> </ul>
	<p><i>Awareness of death:</i> state of people being aware that they are dying.</p> <p>Associated subthemes: No subcategory proposed</p>
	<p><i>Life events:</i> experience of an individual who perceives different moments of his past or future life.</p> <p>Associated subthemes:</p> <ul style="list-style-type: none"> <li>- Actor/observer (notion of seeing or reliving the film of his/her life)</li> <li>- Content of the film (future projections vs. passed)</li> <li>- Imposed vs. free scrolling</li> <li>- Body sensation</li> </ul>



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	- Emotional feeling
	<i>Entrance in the NDE</i> : the moment when people enter the NDE.
	Associated subthemes: No subcategory proposed
<b><i>Transversal theme</i></b>	<i>Altered time perception</i> : depicts a change in NDErs' perception of time.
	Associated subthemes: No subcategory proposed

### 2.1.3.3 Validity and reliability of analysis

As recommended (Malterud, 2001; Miles & Huberman, 1994), several quality criteria were used to ensure the validity of the results and their interpretation: 1) triangulation: two complementary researchers (SD and BP) with different backgrounds (respectively MS in psychology and PhD in public health) performed the analysis; 2) researchers were experimented in qualitative research but novices in the NDE topic, which stimulates the exploration of new insights; 3) for each theme, the number of quotations were counted to get a more precise idea of their importance; 4) intercodage: a Cohen's kappa coefficient was calculated; 5) theoretical validation: done by comparing the results with existing scientific data (see Discussion); 6) an iterative process was then performed. If a new code was introduced, all of the narratives were read again to ensure that the data extraction was complete and to verify that the initial classification was accurate.

## 2.1.4 Results

### 2.1.4.1 Extracted themes

The length of the narratives varied from four lines to three pages. The analysis conducted on the 34 narratives allowed us to distinguish 11 main themes, among which we identified ten time-bounded themes and one transversal theme. A time-bounded theme refers to an event that is relatively isolated within narratives and only occurs during a part of the experience, whereas a transversal theme characterizes the whole experience and is not described as an isolated moment. Moreover, the transversal theme generally appeared in narratives as the result of a retrospective consideration and as a comment of self-reflection on the experience. Arbitrarily selected illustrative verbatim are given in **Table 9**. Themes are detailed in the paragraphs below.

**Table 9. Arbitrarily selected examples of verbatim for each extracted theme.**

NDE theme	Verbatim (gender; age at interview; reported time since NDE)
Light	<p>“I moved forward. I was not walking. I felt attracted by the light and only my will was making me move forward.” (Male; 43 years old; 15 years)</p> <p>“Suddenly everything got spotless white. A very bright white that I had never seen before. As if there were a multitude of rays coming from this light. But it was not dazzling. It was glorious! Beings appeared and then disappeared, as if they were passing through the light.” (Female; 76 years old; 6 years)</p> <p>“The moment after, I was 'integrated' in an intense light that was so white that we cannot even imagine it, not enough words to describe that light. It is not dazzling, but it is extremely powerful, it is powerfully bright.” (Male; 61 years old; 20 years)</p>
Return	<p>“Quiet floating ride around the hospital and finally a meeting with a guy that sees me, hears me, ‘thinks’ me. He gives me the choice between two doors: this one, you go back home, but it will be difficult. OK, I go back, I cannot leave the children alone with their mother. Going back to my body is a</p>

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	<p>horrible pain; I had simply forgotten what life was like, pain and 90% ignorance.” (Male; 50 years old; 15 years)</p> <p>“Everything disappeared all at once and I once again saw the doctors and the firemen taking care of me. The paramedic told me that I just had a cardiac arrest of 30 seconds. 30 seconds only, even though I have the impression that a very long time went by!” (Male; 52 years old; 4 years)</p>
Meeting/encounter	<p>“He talks to me. In fact, he does not talk to me: I am hearing his voice inside of me... I only remember one sentence, and I do not remember if he communicated anything else.” (Male; 61 years old; 20 years)</p> <p>“I was also seeing forms, of a human appearance but beheaded. They inspired me fear.” (Male; 44 years old; 7 years)</p> <p>“I saw my son who died at the age of 23.” (Female; 61 years old; 5 years)</p>
Hyperlucidity	<p>“I felt like I was a genius! I was thinking very fast, everything was working out well for me!” (Male; 64 years old; 9 years)</p> <p>“When my expansion was over, I was everywhere, I was everything at the same time, I was the sky, I was the ground, I was the trees and I felt the wind blowing in my leaves, I was the sea, and I was also my parents, my friends, people I had not met before but who, at that point, I knew because they were part of me. I was genuinely everything at the same time, everything was connected in one way or another.” (Female; 34 years old; 19 years)</p> <p>“My mind is lighter and quicker. It is free to think and to evolve without any restriction. I am still surprised about these infinite possibilities available to me as a mind, impossible to imagine or to realize with a physical body.” (Male; 61 years old; 20 years)</p>
Description of scenes	<p>“I found out I was on a kind of pirogue that followed the flow of a very black river. I was moving toward a bridge where beheaded beings were standing. They extricated other persons from the pirogues that passed under the bridge. They tore away their nails and they tortured them. It was really horrible.” (Male; 44 years old; 7 years)</p> <p>“From a moment to the next I found myself on the top of a hill, overlooking a huge place composed of forests of fir trees and flowers. I felt an indescribable wind, filled with happiness. The sky was filled with magnificent colors that I had never</p>

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	seen before. Clouds passed in the sky rapidly.” (Male; 44 years old; 7 years)
Darkness	<p>“First, I remember being in a dark place, with no walls or rooms. I was wondering what I was doing there.” (Female; 76 years old; 6 years)</p> <p>“I heard a machine then nothing more, no more sound, nothing. I was in an absolute darkness.” (Female; 34 years old; 19 years)</p>
Out-of-body experience	<p>“It all starts with a very clear feeling: the certainty of leaving my body.” (Male; 61 years old; 20 years)</p> <p>“It is when I was transported to go down from the second floor on the stretcher that I had the strange feeling of seeing, from very high above the stairwell, that stretcher carried by four of my comrades that I was hearing as if they were very far. From that height, I could see everything.” (Male; 70 years old; 51 years)</p>
Awareness of death	<p>“I knew I was dead but I felt good, happy.” (Male; 56 years old; 6 years)</p> <p>“I am thinking: « Well, I am dead ». In fact, it is quite pleasant; I abandoned my life, my sick and emotionally troubled body for this marvelous state of well-being and peace.” (Male; 61 years old; 20 years)</p>
Life events	<p>“I do not know how it all began but I saw my life flashing before my eyes, essentially from the age of approximately 2 years old to 18. I had no notion of time. It seems like I was living whole scenes of my life over again. It was a real pleasure to live these happy moments over again, like when I was stealing the cherries from the trees when I was a child. I was feeling good. I did not want that moment to end.” (Male; 62 years old; 5 years)</p> <p>“I wandered for a while in what used to be my life, stopping, from time to time, on some events I had forgotten about or, by contrast, looking with delight at another scene that I had particularly enjoyed. Fragments deeply buried in my memory scrolled. Things that I had completely concealed from my conscious memory. I am surprised to find out about some scenes that seemed to be part of my life and that my memory has decided to overshadow. However, here they are! I am surprised to have done one thing or the other. All of this in a clear and sharp form.” (Male; 61 years old; 20 years)</p> <p>“I experienced visions of my future. Most of the events I saw</p>

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	during my visions occurred in the 9 years following my cardiac arrest. Some of them have not yet occurred but I am deeply convinced that they will come true." (Male; 50 years old; 15 years)
Entrance in the NDE	<p>"After a period of dark night, I found myself standing with no transition in a waiting room." (Female; 51 years old; 11 years)</p> <p>"According to me, it seems that death comes relatively gently, at least in such a case. We open our eyes and we see tons of dancing lights. Even if I didn't live the experience, the sensation of sliding in a bath of liquid nitrogen seems to be the best way to express what I felt. Then, simply, the pain stops." (Male; 50 years old; 1 year)</p>
Altered time perception*	<p>"I am unable to tell how much time it lasted." (Male; 65 years old; 6 years)</p> <p>"This impression of slow motion and of floating is still present within me, as if the notion of space and time had diluted." (Male; 57 years old; 13 years)</p>

\*Transversal theme

### 2.1.4.1.1 Time-bounded themes

**Light:** Considering all narratives, 25 NDE experiencers mentioned seeing a light. This light was attached to a feeling of attractiveness for ten of them. Two NDE experiencers felt enveloped in this light. The description of the light comprised the following characteristics: intense (n=16), white (n=15), indescribable/unusual (n=5), soft and diffuse (n=3), not dazzling (n=3), and yellow (n=1). The physical sensations reported during this experience were an absence of body (n=3) and an absence of pain (n=1). NDE experiencers expressed a feeling of happiness, serenity and tranquility (n=15). The origin of the light was at the end of a tunnel or a corridor (n=9), diffused (it came from everywhere; n=7), or from an unknown origin (n=1).

**Return:** Nineteen individuals detailed the moment they got back from the NDE. Five NDE experiencers received a message that compelled them to get out of the experience. Four of them reported being expelled or ejected from the

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experience. Getting back from the NDE was associated with an intense sleep (n=2) or with a state of confusion (n=2). One NDE experiencer mentioned he had woken up after a period of dark night and three others characterized the return as brutal, without transition. Two narratives included the idea of being brought back into the body. Two NDE experiencers did not remember how it happened. One NDE experiencer attempted to live the experience again (which ended up in failure) and 12 NDE experiencers mentioned an opposition between the feeling of well-being during the NDE and the problems they encountered when they got back to “everyday life”.

**Meeting/encounter:** A meeting with other beings (human or imaginary) was described in 15 narratives. The environment in which this meeting happened varied: a landscape (n=1), a waiting queue (n=1), an office (n=1), in a light (n=4), during a walk (n=1), and on a river (n=1). The message/the content of the interaction was mostly about getting back to life (n=7). The type of interaction with the being also varied: unilateral message (only one being communicates towards the other; n=4), telepathy (n=4), or dialogue (n=3). NDE experiencers mainly saw their interlocutor (n=11), however, others described the sensation of a presence (n=2). The meeting happened with human beings that were unknown to the individual, relatives, family members (deceased (n=8) or not (n=3)), and non-human beings. This experience was accompanied by a feeling of well-being (n=4), an absence of pain (n=3), fear (n=2), unbearable sadness (n = 2), pain (n=1), and confidence (n=1).

**Hyperlucidity:** Fourteen NDE experiencers reported a feeling of power and extreme lucidity. Hyperlucidity was associated with absolute clarity/understanding (n=3), the feeling of being a genius (n=2), clear and quick wit (n=2), or exceptional intelligence (n=1). This experience was in some cases accompanied by a physical release (n=4). Five people described this experience as being accompanied by a sense of power and omniscience: direct control over the thoughts of others (n=2),

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omnipotence (n=2), or having an answer to everything (n=1). Three of them linked this supreme intelligence to the fact of being united with everything that surrounded them, to the global and universal character of this theme. This experience was associated with a feeling of well-being (n=6), a lack of physical pain (n=4), astonishment (n=4), and an inability to describe the feeling (n=1).

**Description of scenes:** Fourteen NDE experiencers provided a detailed description of the setting in which they were immersed. Six of them highlighted the indescribable aspect of the place (i.e., they showed difficulties in finding words). Four NDE experiencers evoked the idea of nature (e.g., vast meadow). This experience was accompanied by an intense feeling of well-being (n=10), a feeling of infinity (n=5), a lack of pain (n=4), astonishment (n=3), and fear (n=1).

**Darkness:** Thirteen participants mentioned the idea of “black” or “dark”. They described a gloomy/dark environment with no objects or way out. For several NDE experiencers (n=7), this darkness occurred in contrast to or following a bright environment. More specifically, NDE experiencers mentioned an absolute darkness (n=7), a gloomy environment (n=5), a gloomy tunnel (n=2), a period of dark night (n=1), and a waiting room with no walls (n=1). Two NDE experiencers described an idea of movement (i.e., passing through a dark night). This experience was associated with the absence or the presence of sound (respectively n=2 and n=1), and the absence of sight (n=2). This theme was linked to varied emotions: fear (n=1), calmness (n=1), and amazement (n=1).

**Out-of-body experience:** Twelve participants reported leaving their body. They “saw” themselves (i.e., observer's perspective). Four of them evoked the awareness of being out of their bodies. A detailed visual description of the emergency situation was reported by nine NDE experiencers. Six of them reported observing the scene from a higher position (positioned above). Three of them reported having felt a real detachment of their body and 1 expressed the feeling of reintegrating his/her body. Two NDE experiencers said they wanted to

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communicate with the people they were observing, in vain. This experience was accompanied by an absence of pain (n=3), thirst (n=1), extreme cold (n=1), and body perception (n=1). The experience was also accompanied by a feeling of well-being (n=7), amazement (n=3), exasperation (n=1), and rejection of the observed body (n=1).

**Awareness of death:** Nine NDE experiencers stated being aware that they were dying.

**Life events:** Eight NDE experiencers out of 34 described a past or future life event. During these visions, they perceived different moments of their past or future lives. Life was reviewed (n=5) or relived (n=2). The vision referred to the future life (n=1) or, in the majority of cases, to the past life (n=6). Three participants stated that life passages comprised an alternation between happy and unhappy moments. These passages were imposed (n=2) or selected (n=1). This life review was associated with curiosity or surprise (n=3), happiness (n=2), difficulties in reviewing (n=2), or with a feeling of indifference (n=1).

**Entrance in the NDE:** Six NDE experiencers detailed the moment they entered the NDE. For three of them, the entrance was progressive and soft. For two others, the entrance followed a period of dark night. Another NDE experiencer wrote he did not know how it all started.

### 2.1.4.1.2 Transversal theme

**Altered time perception:** Sixteen NDE experiencers mentioned a change in the perception of time during their experience. Eight of them expressed a total loss of time marker. Six of them reported an impression of slow motion or the feeling that time had stopped. Finally, three NDE experiencers reported an unusual and



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ineffable perception of time, and therefore described it in an uncommon way (e.g., “integrated time”).

### 2.1.5 Discussion

Since the past three decades, considerable work has been undertaken to describe NDEs in sufficient details, however, most studies have been using closed NDE questionnaires in order to identify the presence of a NDE and assess this phenomenon (e.g., Charland-Verville et al., 2014; Palmieri et al., 2014). Yet, previous studies (Martial, Charland-Verville, Cassol, et al., 2017; Moore & Greyson, 2017; Palmieri et al., 2014; Thonnard et al., 2013) have shown that NDE memories contained more characteristics than other memories of imagined and real events, which highlights the fact that we possess very rich and detailed narratives of these experiences. We therefore aimed to examine all the details stored in NDEs narratives using a qualitative thematic analysis.

One of the major contributions of our study is that it sheds a different light on the structure of the narratives by identifying one “transversal” theme and ten “time-bounded” themes. More specifically, “transversal” themes characterize the whole narrative and do not correspond to a specific moment of the experience. Moreover, the transversal theme (i.e., “altered time perception” in this particular case) is generally addressed retrospectively by NDE experiencers as they reflect upon their experience. On the contrary, “time-bounded” themes have more limited time duration and are generally described as clear isolated events (e.g., OBEs).

The originality of our approach also resides in the design of the study intended to provide new insights regarding the extracted themes. Firstly, the etiology group of our participants was not revealed to the readers until the end of the analysis, and secondly, they were not experts in the field of NDEs. For example, researchers had no knowledge of existing quantitative scales (e.g., Greyson NDE scale; Greyson, 1983) which, in the opposite case, could have had an incidence on

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the extraction process of the themes. By proceeding on this basis, we notably aimed at highlighting themes which might have been left aside in previous studies.

In the end, we identified the “altered time perception” as a transversal theme. This loss of time marker has already been reported in the NDE literature as a defining NDE feature (e.g., Greyson, 1983; Van Lommel et al., 2001). Concomitantly, ten time-bounded themes have also emerged from our analysis, among which seven are similar, or even identical, to the features that are described in the Greyson NDE scale (Greyson, 1983) and the WCEI (Ring, 1980): the vision of a “light”, a “meeting”, “hyper-lucidity”, “darkness”, “OBEs”, “life events”, and “awareness of death”. It is worth noting that some of the themes that have emerged from our qualitative thematic analysis include several features of the Greyson NDE scale (e.g., “life events” include “life reviews” as well as “precognitions”). Besides, some of the components we have identified are less specific. For instance, we identified the theme “light” whereas the Greyson NDE scale focuses on a “brilliant”, “unusual” or “mystical” light.

In parallel, readers identified three additional themes that partly overlap with the features identified by Greyson (1983) and Ring (1980), namely, “entrance in the NDE”, “return” and “description of scenes”. These themes however seem to be described differently and to integrate complementary information and details. Indeed, for the theme “entrance in the NDE” some NDE experiencers remembered and spontaneously detailed the way their NDE began, abruptly or progressively. As regard to the other two themes, “return” and “description of scenes”, it must be noted that they somehow overlap with existing features assessed by the widely used Greyson NDE scale. If we consider, in the first instance, the theme “return”, we can establish the link with the concept of “border” raised by the scale. Indeed, the theme encompasses the decision to get back to life and the fact that some NDE experiencers felt like they were sent back against their will. Yet, the theme “return” is broader than Greyson's feature as it also comprises the way NDE experiencers

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felt when returning to “usual awareness”, and the substantial gap that exists between the emotions experienced during the NDE and during everyday life. Indeed, part of the NDE experiencers emphasized the opposition between the feeling of well-being during the NDE and the problems encountered or the pain they felt when they got back from their NDE. It is our view that this latter finding could at least partially explain some of the beneficial consequences of NDEs such as a reduced fear of death (Greyson & Harris, 1987). The way NDE experiencers came back from their NDE (Moody, 1975) and how resentful and frustrated they could feel about it (Schwaninger et al., 2002) have already been brought to light by some authors, and we therefore believe that this issue deserves careful consideration in the future. Second, the theme “description of scenes” could lead one to think to the unearthly world reflected in the Greyson NDE scale. Nonetheless, this theme not only includes unfamiliar and mystical places but also comprises the description of the setting in which NDE experiencers found themselves during their NDEs (e.g., an operating room or the scene of the incident). Interestingly, even though some of the places they saw were portrayed as ineffable and indescribable, participants endeavored to detail them. To our knowledge, no NDE questionnaire formally investigates those three themes and we believe that further work should be done to collect them more systematically. Furthermore, it could be interesting to explore the way they are described in narratives relating NDEs of other etiologies.

Overall, these results corroborate the content of existing tools such as the Greyson NDE scale (Greyson, 1983), but also highlight new aspects of NDEs that could be further investigated in future studies. This recurrence in the extracted themes/features supports the view of authors such as Facco, Agrillo, and Greyson (2015) who suggest that NDE testimonies from all around the world show sufficient commonality to consider NDEs as “universal human experiences”. In addition to outlining the structure of narratives, text analyses explore the context of reported themes and provide detailed descriptions of NDEs. In our sample, the “light”, usually qualified as “brilliant”, “unusual” or “mystical” in the NDE literature (e.g.,

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Greyson, 1983), is also described as “soft”, “diffuse” and “white” – interestingly, the majority the NDE experiencers who saw the light depicted a white light. Besides, NDE experiencers evoked a variety of strong feelings to describe most of the extracted themes and depicted a wide range of emotional states. Indeed, they not only mentioned feelings of peace or joy but also reported feelings of astonishment, amazement, surprise and fear to describe the identified themes. In addition, it is worth noting that negative feelings such as fear are also comprised in positive NDEs. This wide range of emotions partly explains the fact that the feature “feelings of peace, pleasantness or joy”, consistently reported in other studies on cardiac arrest survivors (e.g., Charland-Verville et al., 2014; Greyson, 2003; Parnia et al., 2001), has not been high-lightened as a key element following our analysis. Even though pleasant feelings were frequently reported, readers considered that their identification as a key theme would have masked the diversity of the emotions felt by NDE experiencers, especially negative ones. In addition, readers judged that positive feelings, such as pleasantness or joy, did not appear as a theme on their own but rather characterized some of the other themes that have been identified by the readers. As a matter of fact, “light”, “hyper-lucidity”, “OBEs” and “awareness of death” are generally associated with positive feelings (e.g., well-being, happiness, serenity or amazement). On the contrary, “meeting”, “darkness”, “life events”, “description of scenes” and “return” are related to conflicting emotions. Finally, “entering the NDE” and “altered time perception” rarely have an emotional value. In most cases, NDE experiencers seem to use a wide range of qualifiers to describe their experience, which makes each narrative unique. In a nutshell, it has to be underlined that the keyness of a theme in qualitative analysis does not fundamentally lie on quantifiable measures but rather depends on the researcher's judgment based on the content of the accounts (Braun & Clarke, 2006).

Existing questionnaires, such as the Greyson NDE scale, allowed researchers to gather data and identify NDE experiencers. Nonetheless, these tools

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do not offer the possibility to distinguish between NDEs of different etiologies, or between classical NDEs and “NDE-like” experiences. In addition to the use of those scales, we believe that thematic analysis, combined with other types of qualitative analysis methods such as discourse analysis (Starks & Brown Trinidad, 2007), should help to explore this issue further. Yet, qualitative analysis methods require good quality narratives and appropriate data collection. In this sense, it would be interesting to have a more systematic approach for data collection in order to obtain more detailed narratives. Semi-structured interviews are recommended in such a framework, requiring well-constructed interview guides. Moreover, it could be of a great interest to look into the meanings attached to such experiences and to analyze how NDE experiencers reflect upon NDEs and their consequences on their lives. Besides, out of concern for methodological rigour, only narratives that scored 7 or more on the Greyson NDE scale were included in our study sample. Still, it would be interesting to carry out analyses on the narratives of all the NDE experiencers who have contacted us after a cardiac arrest, without taking any cut-off score into account.

Finally, some issues remain to be addressed. First, the sample size in the present study is limited. Qualitative research is, however, very intensive and time consuming, which makes analysis of large samples impractical. Indeed, sample size in qualitative research is frequently much smaller than in quantitative study and generally does not exceed 50 participants (Pope, Van Royen, & Baker, 2002). Besides, given the preliminary use of the presented methodology, we decided in the first instance to restrict the analysis to the narratives of people who had lived comparable life-threatening situations, namely a cardiac arrest. As already mentioned above, it would however be of a great interest to invest in further analysis of reports depicting other types of experiences such as “NDEs-like” or close brushes with death that did not lead to a NDE. Second, because NDE experiencers voluntarily contacted us, our sample might suffer from a self-selection bias. Due to the mystical connotation of these experiences, and because they may be perceived

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as negative and upsetting, some people might feel reluctant to share these events. Lastly, narratives were collected retrospectively and time elapsed since the NDE varies which could represent a source of potential bias. Indeed, one can hypothesize that NDE experiencers' narratives may have been tainted by descriptions of the phenomenon in the media and in lay literature. Consistent with this hypothesis, Charland-Verville and collaborators (2014) pointed out that some NDE features seemed to be more frequent in retrospective designs. We underline, however, that Greyson (2007) had highlighted, prior to that, the consistency of NDE memories over a period of two decades. Given this potential bias and the ineffability of the experience, it would be interesting to collect NDE accounts and look into the terms used by NDE experiencers when recovering from their coma and depicting the experience for the first time. These observations and potential biases call for further studies to analyze prospective trials using thematic analysis method.

## 2.2 Study 2. Distressing near-death experience accounts

### 2.2.1 Summary

NDEs are usually associated with positive affect, however, a small proportion is considered distressing. We aimed to look into the proportion of distressing NDEs in a sample of NDE narratives, categorize distressing narratives according to Greyson and Bush's classification (inverse, void or hellish), and compare distressing and "classical" NDEs. Participants wrote down their experience, completed the MCQ and the Greyson scale. The proportion of suicidal attempts, content and intensity of distressing and classical NDEs were compared using frequentist and Bayesian statistics. Distressing NDEs represent 14% of our sample (n=123). We identified eight inverse, eight hellish and one void accounts. The proportion of suicide survivors is higher in distressing NDEs as compared to classical ones. Finally, memories of distressing NDEs appear as phenomenologically detailed as classical ones. Distressing NDEs deserve careful consideration to ensure their integration into experiencers' identity.

## 2.2.2 Introduction

Although generally described as pleasant and leading to positive changes, a small proportion of NDEs has been depicted as negative and sometimes “hellish”. To date, only a few studies have addressed these distressing experiences and we do not precisely know their causes and potential consequences (Bush, 2002; Greyson & Bush, 1992). Moreover, their prevalence seems to vary widely. For example, most early studies on NDEs only depicted positive emotions (Greyson & Stevenson, 1980; Ring, 1980). Lindley and collaborators (1981) however published an interdisciplinary study in which they identified 55 NDE experiencers, of which eleven reported “negative” experiences (including one “hellish”). More recently, a study by our group (Charland-Verville et al., 2014) pointed out that 10% of the sample did not describe positive emotions. Overall, we should note that the heterogeneous set of tools used to identify negative NDEs might strongly influence the data. Moreover, some of these numbers may underestimate the actual percentage. Indeed, although NDEs seem to come out of the taboo atmosphere, some NDE experiencers might still feel reluctant to share them. This could be even more the case when these experiences are perceived as distressing or upsetting, as memory retrieval may be painful and as people might feel stigmatised (Greyson & Bush, 1992). Besides, as stated by Greyson and Bush (1992), current widely used NDE questionnaires, such as the Greyson NDE scale (Greyson, 1983) and the WCEI (Ring, 1980), only focus on positive emotions and might fail in identifying these distressing experiences. Only a small number of empirical studies have addressed distressing NDEs in-depth. In addition, most of them have focused on single cases, thereby affecting the generalisability of their observations (Bonenfant, 2001; Irwin & Bramwell, 1988). One noteworthy finding is the existence of experiences beginning the same way as classical NDEs, but that suddenly become negatively toned. To learn more about the content of distressing NDEs, Greyson and Bush (1992) looked closely into the content of 50 self-reported accounts and identified



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three subcategories of frightening experiences. Firstly, those containing features similar to classical NDEs, with the exception that the NDE experiencer considers the whole experience as unpleasant. According to these authors, it is the most frequently reported type. These distressing NDEs had already been described by Ring (1994) who called them “inverse”, with reference to their resemblance with classical NDEs. Secondly, those in which the NDE experiencer is in an isolated and eternal void (i.e., “void” NDEs). Finally, the rarest type, “hellish”, is described as experiences of visiting hell-like regions and encountering demonic beings. Later, Rommer (2000) suggested a fourth type in which NDE experiencers are heavily disturbed by a life review. This category has however been classified by Bush (2002) as a subset of the “hellish” experiences. Although there has been an indication about the relative size of the different categories, the occurrence of these three subcategories in the reported sample has not been supplied. In addition, even though this pioneer article illustrates distressing experiences by providing numerous verbatim accounts, to date, no study has performed a rigorous analysis of the phenomenology of these subtypes of NDEs by multiple coders.

Regarding potential causes, the unpredictable aspect of NDEs makes it difficult to identify the psychological and physiological status before a distressing experience (Greyson & Bush, 1992). The literature has often suggested a relationship between the negative emotional context of suicides and the nature of the resulting NDE (Greyson & Stevenson, 1980; Ring & Franklin, 1982). However, even if this relationship remains largely under-explored, Ring and Franklin (1982) have reported that suicide-related NDEs are not different from NDEs in general. Overall, the few available scientific data and the potentially long-lasting emotional trauma triggered by frightening NDEs advocate for further rigorous studies (Bush, 2002).

In this respect, we aim to (1) look for the proportion of “distressing” NDEs in a relatively large sample of self-reported NDE narratives; (2) classify the

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distressing narratives by multiple assessors, in order to have a precise estimate of the occurrence of the three subtypes of “negative” NDEs; and (3) compare memories of distressing and “classical” (i.e., experiences comprising typical features and not perceived as negative) NDEs on the basis of their content, intensity, phenomenological details and proportions of suicidal attempts.

## 2.2.3 Materials and methods

### 2.2.3.1 Participants and procedure

#### 2.2.3.1.1 Participants

Participants were initially recruited following calls for NDE testimonies via the websites, the appearances in local media and the publications of the Coma Science Group (GIGA Consciousness, University and University Hospital of Liège, Belgium) as well as the IANDS (France and Flanders). They were then mailed questionnaires including items relating to socio-demographic (gender, age at NDE, age at interview) and clinical (time since NDE, presence of a loss of consciousness exceeding one hour) characteristics. Participants, who were not aware of the specific purpose of the research, were subsequently invited to freely write down a detailed description of the experience on blank sheets of paper, with no restriction regarding text size. Lastly, they were asked to complete the Greyson NDE scale (Greyson, 1983) in order to identify “true” NDEs using a cut-off score of 7 (Greyson, 1983; Lange et al., 2004), as described previously. We only included experiences equal or above the cut-off score of 7 that occurred following a severe brain injury accompanied by a period of coma (loss of consciousness exceeding one hour) and a hospitalisation in an intensive care unit. Additionally, participants filled out a short version (D’Argembeau & Van der Linden, 2008) of the MCQ (Johnson et al., 1988). It includes 16 items (each rated on a 1–7 points Likert scale) assessing the following categories of memory characteristics: memory clarity, sensory details, self-referential and emotional information, reactivation frequency, and confidence in the memory. The study was carried out in accordance with the recommendations of the ethics committee of the Faculty of Medicine of the University of Liège. The protocol was approved by the ethics committee of the Faculty of Medicine of the University of Liège. All participants completed a written informed consent in accordance with the Declaration of Helsinki.

### 2.2.3.1.2 Classification of distressing experiences

The first step consisted in identifying distressing NDE narratives. To that end, we evaluated responses at item 14 of the short version of the MCQ (i.e., "When the event happened, my emotions were: -3 = "very negative", 0 = "neutral", +3 = "very positive"") and selected the narratives that were rated between -1 and -3. All written narratives were therefore divided into two main emotions-related groups (i.e., distressing NDEs and "classical" NDEs). The dataset, including distressing narratives that had to be classified into three subtypes (i.e., inverse, void and hellish), was created and composed of five Dutch and 12 French narratives. Their average length was of 975 words per account (ranging from 206 to 4795). A detailed description of the subtypes (Greyson & Bush, 1992) was provided to coders (i.e., two Dutch speakers and two French speakers). Each account was then independently read by the two coders who perfectly mastered the language in which it was written. NDE features corresponding to each of the three subtypes were highlighted in different colours. The pre determined features corresponding to each type of distressing NDE can be found in **Table 10**. The number of observed agreements was 5/5 for Dutch narratives and 11/12 (92%) for French narratives.

Inter-rater reliability was assessed using a Cohen's kappa coefficient. The closer the value to 1, the better the concordance is between coders (Landis & Koch, 1977). We obtained a Cohen's kappa coefficient of 1 ("perfect" agreement) for Dutch narratives and of 0.855 (95% confidence intervals 0.583-1; "very good" agreement) for French narratives. Discrepancy was discussed in order to reach a final unanimous categorisation.

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**Table 10. General description and features belonging to distressing near-death experiences subtypes.**

Type	General description and features
<b>Inverse</b>	Narratives contain classical NDE features but the event is considered as unpleasant (Greyson & Bush, 1992) Coders considered features described in the two most used NDE scales (i.e., Greyson NDE scale and Weighted Core Experience Index –WCEI– scale (Greyson, 1983; Ring, 1980): 1) intense feeling of joy, 2) peacefulness, 3) altered time perception, 4) accelerated thoughts, 5) vision of scenes belonging to one’s past/life review, 6) sensation of understanding everything (about oneself, others or the universe), 7) feeling of harmony with the universe, 8) vision of a very bright light, 9) communication with a light, 10) vision of/moving through a tunnel, 11) more vivid senses than usual, 12) being aware of things happening elsewhere, 13) visions of the future, 14) out-of-body experience, 15) entering a non-terrestrial world, 16) encounter with a mystical being/voice, 17) vision of dead or religious spirits, 18) coming to a border/point of no return, 19) awareness of being dead, 20) observation of colors, 21) observation of a celestial landscape, and 22) darkness.
<b>Void</b>	Narratives might contain features belonging to the classical type but in a smaller amount. Void accounts should also involve 1) an acute awareness of nonexistence, 2) the sensation of being completely alone forever in an absolute void, and/or 3) receiving a convincing message saying that the real world never existed (Greyson & Bush, 1992).
<b>Hellish</b>	Narratives might also contain features belonging to the prototypical type and to the void type. This subtype should also encompass hellish imagery and sounds such as 1) the vision of an ugly or foreboding landscape, 2) the presence of demonic beings, 3) hearing loud and/or annoying noises, 4) seeing frightening animals and/or 5) encountering other beings in extreme distress (Greyson & Bush, 1992).

### 2.2.3.2 Statistical analysis

We calculated the proportion (%) of distressing NDEs by taking into account all the NDE experiencers that had provided us with a written narrative and who had duly completed all questionnaires (i.e., Greyson NDE scale and MCQ) since the beginning of enrolment in 2010. NDE experiencers who reported distressing NDEs were compared to those who reported classical NDEs regarding demographical and clinical information. Differences between groups were assessed using Student’s t-

## Study 2. Distressing near-death experience accounts

tests (for age at NDE, age at interview and time elapsed since NDE) and Fisher's exact tests (for etiology and gender). Results were considered significant at an alpha of 0.05 ( $p < 0.05$ ) and were expressed as mean  $\pm$  SD for quantitative variables and as counts and proportions (%) for the qualitative variables.

Regarding answers at questionnaires, Greyson NDE scale scores distributions being skewed and the answers at the MCQ being ordinal data measures, distressing and classical NDEs were compared using Mann Whitney U tests and results were expressed as median (IQR). We corrected for multiple comparisons using a Bonferroni correction, setting the criterion for statistical significance at  $p < 0.0125$  for the Greyson NDE subscales scores and at  $p < 0.003$  for the 16 items of the MCQ. The item relating to the valence was included in our analysis to ensure a clear difference between the two emotions-related groups. As a second step, and in accordance with recent recommendations (Dienes, 2014), we conducted Bayesian Mann–Whitney tests in addition to frequentist inferential analyses. Indeed, unlike classical inference methods which can only provide evidence against the null hypothesis, Bayesian methods have the advantage of quantifying the evidence for and against it (Dienes, 2014). Regarding data interpretation, we considered a Bayes Factor (BF) of  $< 3$  as anecdotal evidence, between 3 and 10 as moderate evidence, between 10 and 30 as strong evidence, between 30 and 100 as very strong evidence, and higher than 100 as decisive evidence for the model tested relatively to the null or to another model (Lee & Wagenmakers, 2014). BF indicates Bayesian evidence for the presence of an effect relative to the null, and BF indicates evidence for the null. Data analyses were carried out using SPSS (Statistical Package for the Social Sciences, version 22.0, SPSS Inc., Chicago, IL, USA) and with the 0.9.0.1 version of the JASP software package for Bayesian analyses, using default settings for prior distributions.

## 2.2.4 Results

### 2.2.4.1 Demographic data

We received the testimonies from 506 participants since the beginning of the enrolment in 2010. Among these, 123 individuals met the criteria of an NDE (i.e., Greyson NDE scale cut-off  $\geq 7$ ), had duly completed questionnaires and were included in our analyses, of which 17 were classified as distressing (14%). The distributions of demographic data of the two emotions-related subsamples follow a normal distribution. Distressing and classical NDE experiencers do not differ in terms of gender and age at NDE. Distressing NDE experiencers however include more suicide survivors, and classical NDE experiencers appear to be older at the time of the interview and to present a longer time elapsed since NDE (see **Table 11**).

**Table 11. Demographical information of NDE experiencers who lived a distressing NDE vs. a classical NDE.**

	Distressing NDEs (n=17)	Classical NDEs (n=106)	<i>p-Value</i>		
Gender – female N(%)	12 (71)	61 (58)	0.43		
Etiology – suicide attempt N(%)	4 (24)	1 (1)	<0.001*		
			<i>t</i>	<i>p-Value</i>	$G_{Hedges}$ (CI <sub>95</sub> )
Age at NDE Mean in years( $\pm$ SD)	34 (17)	32 (17)	0.36	0.723	-0.118 (-0.63- 0.395)
Age at interview Mean in years( $\pm$ SD)	50 (12)	57 (11)	-2.417	0.025*	0.629 (0.11- 1.174)
Time since NDE Mean in years( $\pm$ SD)	16 (16)	24 (17)	-2.075	0.049*	0.474 (-0.041- 0.99)

\*Results are significant. CI = Confidence interval.

### 2.2.4.2 Classification of distressing experiences

The final classification of all narratives includes 8 inverse, 8 hellish and 1 void (see **Table 12** for an example of each subtype of distressing NDE narratives). Additionally, the text analyses revealed that out of the 17 distressing narratives, 6 clearly mention the presence of positive feelings at the beginning of the experience in their written narrative (i.e., peacefulness and/or joy).

**Table 12. Text excerpts of written distressing NDE narratives.**

Type	Selected text excerpts translated from French (gender, age at interview)
<b>Inverse</b>	<p>“First, I was sucked into a tunnel. Then, there was a descent into this tunnel. At an incredible speed. Perhaps the speed of light. A speed that does not last, a flash. It is hard to describe in words, it is very different from what I have experienced in the ‘normal’ world. This speed gives me the sensation of ‘no time’. In this tunnel, I saw flashes, ‘animated’ faces of missing people that I had loved (brother, grandfather). The smile of a little boy murdered when I was five, and lots of people I did not know. I experienced this ‘journey’ three times. Each time I came back to life. I was trying to tell the doctor that I was going back into the tunnel, that I would die again, but no sound came out of my mouth. At some point, the anesthesiologist said: ‘She tries to speak, I do not understand anything’. My mind was talking, screaming, calling for help. But nothing, no reaction, as if I was in a parallel world. I suffered terribly physically, I was exhausted, I felt abandoned by living beings. I struggled, completely alone, I did not want to join all these dead beings, although they were welcoming, reassuring. I knew I would die but I was not ready to give in to the temptation of rest”. (female, 57 years old)</p>
<b>Hellish</b>	<p>“There are more and more entities surrounding me and this dark environment is unbearable. The deafening noise invades the space that becomes increasingly dark. I would like this noise to stop. I am caught in a whirlwind, the dark gray haze around me is thick, and the smell and sound are getting more unbearable (...). And I am beginning to distinguish forms in this incredibly thick fog. Human, bestial, monstrous. I am swimming in a stinking stench filled with horrible and furtive creatures and I am feeling overwhelmed with pain. It hurts everywhere, no, worse, I am becoming pain. I understand that my suffering is just beginning. And I am scared. A growing fear, appalling. I would like to close my eyes and stop hearing and feeling. But it is impossible. My vision is very wide, I see everywhere at once, I see in front of me, above, below and on the sides; only a small part</p>



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	<p>on the back is not visible. The less I want to hear, see and feel, the more receptive I am. It is terrible, it is like I am absorbing the pain and suffering of all these beings... I am extremely lucid, I feel aware like I have never been before. Time no longer exists. I wish I could escape this place, escape time, but my anguish is such that I cannot move... as if these beings were holding me back. (...) I understand that I am between two worlds and that this in-between is none other than Hell". (female, 42 years old)</p>
<b>Void</b>	<p>"I was in the dark. Time did not exist anymore. I did not have a physical body but the impression of being above it. There was no suffering. I was nothing. Then, below me, I saw an accident, I saw a girl. She suffered horribly because she was screaming. It hurt to hear her shouting so loud. Then, everything happened very quickly. This shouting person was me. I tried to get up, I screamed and I fell back. Anxious, I told to myself: 'I am dead. I do not want to stay in the dark, I want to go to paradise. I have the right to go, I have always done everything properly'. I was floating into the dark, unaware of what was happening around me. A presence came near me and told me in a loud, clear, authoritarian voice: 'Paradise does not exist!'. Self-confident, I answered that this is not true and I explained that I have never committed sins. (...) The voice repeated: 'After death, it is over, there is nothing'. Teachers, priests and sisters taught me that if you never commit mortal sins, you go to heaven. I wanted to go to heaven. The clear and firm voice told me: 'All those who taught you that lied to you, after death there is nothing!'. (...) The voice disappeared. No more voice, nothing, it was over. I was desperate, I was crying. Then I fell into an endless darkness at full speed. Always faster. There was nothing to stop me from falling. I was looking around to grab something. I realized there was nothing. It was total black. I was never going to stop falling". (female, 60 years old)</p>

### 2.2.4.3 Comparison of distressing and classical experiences

The comparison of distressing and classical NDEs regarding intensity (i.e., Greyson NDE scale total scores) and content (i.e., Greyson NDE scale components) revealed that distressing experiences show lower scores on the affective component ( $p < 0.001$ ). This was supported by Bayesian analyses which showed decisive evidence in favour of a difference between groups (see **Table 13**). By contrast, distressing and classical accounts do not seem to differ regarding total score as well as on the three other components of the Greyson NDE scale (i.e.,

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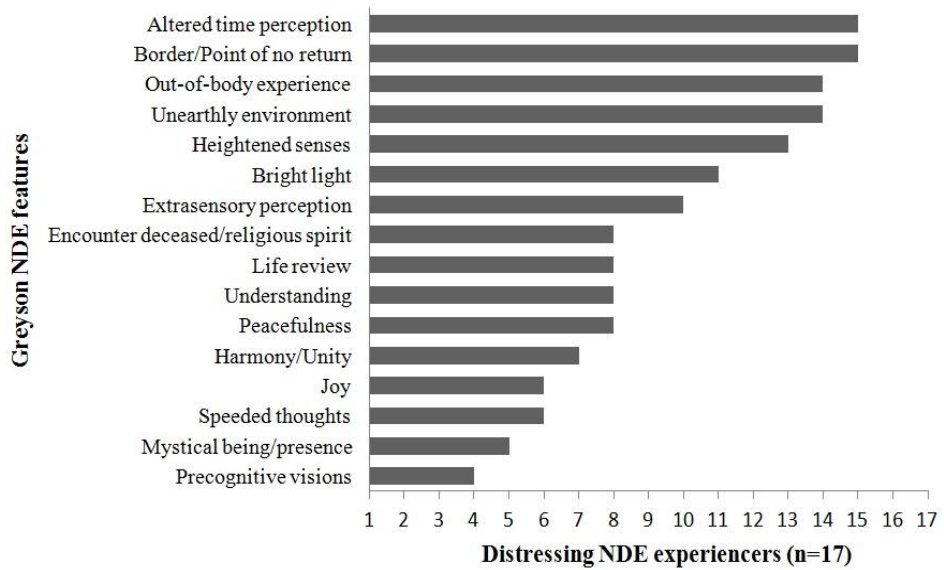
cognitive, paranormal and transcendental – see **Table 13**); Bayesian analyses provided positive evidence for the *absence* of a difference. The number of distressing NDE experiencers recalling each type of classical NDE feature included in the Greyson NDE scale can be found in **Figure 3**. Regarding the amount of memory details, the comparison of distressing and classical NDEs revealed a difference regarding emotions felt at the time of the event (i.e., valence) but the other items did not differ; this was supported with Bayesian evidence for the null effect for the majority of items (see **Table 14**). More specifically, our results indicate stronger evidence for no difference between distressing and classical NDEs in terms of self-reported memory clarity, sensory details, self-referential information, reactivation frequency, and confidence in the memory. This was also the case for emotion-related items, such as the personal importance and the feelings experienced while remembering. To ensure our results are not caused by the effect of confounding variables, we performed the analyses by controlling for age at interview and time since NDE, which led to similar results.

**Table 13. Score differences between distressing and classical NDEs on the Greyson NDE scale.**

	<b>Distressing NDEs (n=17)</b>	<b>Classical NDEs (n=106)</b>	<b><math>W_s</math></b>	<b><math>p</math>-value</b>	<b><math>R</math> (<math>CI_{95}</math>)</b>	<b><math>BF_{10}</math></b>	<b><math>BF_{01}</math></b>
<b>Affective component</b>	2	6	296.5	<0.001*	-0.404	42.276	0.135
<b>Median(IQR)</b>	(1-4)	(4-7.75)			(-0.542--0.245)		
<b>Cognitive component</b>	3	3	963.5	0.645	-0.042	0.482	2.076
<b>Median(IQR)</b>	(2-5)	(2-6)			(-0.217-0.136)		
<b>Paranormal component</b>	4	4	1018.5	0.385	-0.079	-0.303	5.701
<b>Median(IQR)</b>	(3-6)	(2-5)			(-0.252-0.099)		
<b>Transcendental component</b>	4	4	862.5	0.779	-0.026	0.207	4.822
<b>Median(IQR)</b>	(3-4)	(2-6)			(-0.202-0.151)		
<b>Total score</b>	14	16	667.5	0.09	-0.155	0.357	2.803
<b>Median(IQR)</b>	(13-16)	(12-21)			(-0.323-0.022)		

Results for the components are considered statistically significant at  $p < 0.01$  after Bonferroni correction. \*Results are significant.  $BF_{10}$ =evidence in favour of an effect of the valence (distressing vs. classical) on the scores at the Greyson NDE scale.  $BF_{01}$ =evidence in favour of a null effect of the valence (distressing vs. classical) on the scores at the Greyson NDE scale.

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**Figure 3** – Number of distressing NDE experiencers recalling each NDE feature by decreasing order.

**Table 14. Score differences between distressing and classical NDEs on the MCQ.**

<b>MCQ Items</b>	<b>Distressing NDEs Median (IQR)</b>	<b>Classical NDEs Median (IQR)</b>	<b>Ws</b>	<b><i>p</i>-value</b>	<b>R (CI95)</b>	<b>BF10</b>	<b>BF01</b>
<b>Feeling of re-experiencing</b>	6(5-7)	6(5-7)	908.5	0.957	-0.005 (-0.181-0.172)	0.248	4.357
<b>Visual details</b>	7(6-7)	7(6-7)	1015	0.346	-0.085 (-0.258-0.093)	0.289	3.684
<b>Other sensory details</b>	5(3-7)	4(1-6)	1091.5	0.154	-0.129 (-0.299-0.049)	0.340	1.989
<b>Location</b>	7(3-7)	7(6-7)	756	0.183	-0.120 (-0.29-0.058)	0.265	4.584
<b>Time</b>	4(1-7)	3(1-6)	993	0.483	-0.064 (-0.238-0.114)	0.559	4.161
<b>Coherence</b>	7(5-7)	7(6-7)	789.5	0.421	-0.074 (-0.247-0.104)	0.264	4.255
<b>Verbal component</b>	4(3-5)	2(1-5)	1077	0.190	-0.119 (-0.289-0.059)	0.906	4.259
<b>Feeling emotions</b>	7(5-7)	6(5-7)	958	0.612	-0.046 (-0.221-0.132)	0.219	4.621
<b>Real/imagined</b>	7(6-7)	7(7-7)	819.5	0.466	-0.066 (-0.24-0.112)	0.308	3.715
<b>One's own actions</b>	7(3-7)	7(5-7)	851	0.790	-0.025 (-0.201-0.152)	0.222	4.159
<b>One's own words</b>	6(4-7)	6(1-7)	990.5	0.448	-0.069 (-0.243-0.109)	0.363	4.438
<b>One's own thoughts</b>	7(6-7)	7(5-7)	1069	0.149	-0.131 (-0.041-0.284)	0.267	4.339

<b>Visual perspective</b>	6(2-7)	6(4-7)	740	0.214	-0.113 (-0.284-0.065)	0.199	4.365
<b>Valence</b>	1(1-3)	7(6-7)	143	<0.001*	-0.559 (-0.669- -0.424)	64911	<0.001
<b>Personal importance</b>	7(6-7)	7(6-7)	899	0.989	-0.002 (-0.178-0.175)	0.593	3.768
<b>Reactivation frequency</b>	7(5-7)	6(4.25-7)	996	0.460	-0.067 (-0.241-0.111)	0.264	4.766

Results for the MCQ items are considered statistically significant at  $p < 0.003$  after Bonferroni correction. \*Results are significant.  $BF_{10}$ =evidence in favour of an effect of the valence (distressing vs. classical) on the scores at the MCQ.  $BF_{01}$ =evidence in favour of a null effect of the valence (distressing vs. classical) on the scores at the MCQ.

## 2.2.5 Discussion

Our main goal was to better document distressing NDEs which remain poorly studied (Bonenfant, 2001; Bush & Greyson, 1994; Greyson & Bush, 1992; Irwin & Bramwell, 1988). This study investigated three major aspects of these experiences: (1) the proportion of distressing NDEs in our sample, (2) their distribution according to the three categories previously established by Greyson and Bush (1992), and (3) the phenomenological and contextual differences existing between the memories of distressing and classical NDEs. With regard to our first aim, the data suggests that distressing NDEs represent 14% of our total NDE sample. Earlier studies generally reported percentages ranging from 1% to 10% (e.g., Charland-Verville et al., 2014; Greyson & Bush, 1992). These different proportions can be attributed to the very broad definitions of distressing NDEs, as well as the varying methodologies. By contrast with previous research, we used a rigorous methodology to identify distressing NDEs (i.e., an item asking participants to rate their emotions at the time of the NDE). An additional plausible explanation is that the distressing dimensions of the experience, added to its mystical aspect, could deter people from sharing it. A combination of the aforementioned factors could contribute to the observed discrepancies. Our second objective was to replicate Greyson and Bush's (1992) classification of distressing NDEs in order to give a more accurate estimate of the number of narratives belonging to each subtype. Indeed, the aforementioned authors did not indicate the number of accounts belonging to each category and what proportion represents their sample of distressing narratives when considering their own database of testimonies. Interestingly, our distribution is not fully in line with the results obtained by Greyson and Bush (i.e., in decreasing order of frequency: the inverse, the void and the hellish NDE; (1992). Indeed, the present sample presents an equal number of inverse and hellish NDE narratives and only one void experience. Although the exact distribution differs, analyses seem to confirm Greyson and Bush's (1992)

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classification. Rommer (2000) proposed a fourth type composed of a life review during which the NDE experiencer feels negatively judged by a higher power being. We effectively found one distressing narrative that included this feature and could match this category but, in accordance to Bush's (2002) view, it was categorised as hellish. To date, little is known about the resulting consequences of these subtypes of NDEs. Bush and Greyson (1992) however described three possible responses to frightening NDEs: (1) the negative event may be perceived as a warning about unwise behaviours, may lead to a self-analysis and ultimately to a "turn around" in one's life; (2) NDE experiencers may treat the event as if it did not matter; and (3) the frightening event may result in a difficulty to integrate the experience and in the development of a sense of stigma. As already stated by Bush and Greyson (1992), the literature on post-traumatic growth in NDE experiencers still remains under documented and deserves further research.

Regarding our last aim, distressing and classical NDEs were found to have comparable total scores on the Greyson NDE scale. A detailed analysis revealed that these two types of experiences only differed on the affective subscale. Those findings were expected since three items clearly stipulate the presence of positively connoted emotions. Moreover, the bright light, often described in NDE narratives (Charland-Verville et al., 2014), is known to be often associated with positive emotions such as feelings of happiness, serenity and tranquillity (Cassol et al., 2018; Facco & Agrillo, 2012). As previously stated in Greyson and Bush (1992), scales such as the WCEI (Ring, 1980) or the Greyson NDE scale (1983) seem to place a high value on positive feelings and may therefore be biased and lack sensibility in the identification of negative experiences. It is however interesting to note that, although distressing experiences are significantly less positive, we do not only observe zero values on the affect component of the Greyson NDE scale. By means of a rigorous text analysis, we identified the presence of positive emotions in distressing NDE narratives and highlighted the presence of peacefulness feelings in the beginning of several accounts. Our results therefore seem to corroborate



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previous studies describing a combination of blissful and frightening elements in some distressing NDEs (e.g., Bonenfant, 2001; Sabom, 1982). Thus, it should also be emphasised that these distressing experiences could be misinterpreted as positive on the unique basis of the Greyson NDE scale. In parallel, results indicate that memories of distressing NDEs are likely to contain as much overall phenomenological details as memories of classical NDEs. A Bayesian analysis revealed no evidence in favour of a difference between the memories of these two types of events, except for the valence. Given that the MCQ allows the assessment of the subjective experience associated with remembering an event (Johnson et al., 1988), this indicates that compared to memories of classical NDEs, memories of distressing NDEs are associated with a comparable memory clarity, as well as a similar amount of sensory, self-referential and emotional details (i.e., personal importance and feelings experienced while remembering). Moreover, they seem to be retrieved in memory at the same frequency as memories of classical NDEs. Finally, both kinds of NDE experiencers present the same level of confidence in their memory and appear to assign comparable personal importance to the experience. Therefore, our results showed that the memory of distressing NDEs contains a similar level of self-reported phenomenological details as the memory of classical NDEs which are known to be vivid and highly detailed (Thonnard et al., 2013). Finally, we observed a higher proportion of suicidal attempt context in distressing NDE experiencers. Thereupon, we speculate that the negative context surrounding NDEs may have partly influenced their emotional valence. In accordance with neuroscientific and psychological approaches to NDEs (Blackmore, 1993), we hypothesise that their content, in this case the emotional valence, could be influenced by “top-down” processes (i.e., NDE experiencers’ knowledge, beliefs and expectations) that are more influential when sensory information is degraded (e.g., altered states of consciousness) or ambiguous.

Overall, we believe that future research should essentially focus on the exploration and understanding of the consequences of these distressing

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experiences. Past studies focusing on classical NDEs have found that these experiences are self-defining (Cassol, D'Argembeau, Charland-Verville, Laureys, & Martial, 2019) and have a powerful force of personal change generally reported as very positive (Schwaninger et al., 2002; van Lommel et al., 2001). Moreover, through their model of sense-making processes and assimilation problems, Bianco, Sambini and Palmieri (2017) have shown that making sense of a NDE can be a problematic issue, notably because one's previous models about the world may be incongruent with the unusual nature of the NDE-related information. It could therefore be reasonable to think that distressing NDEs might have some powerful negative consequences on NDE experiencers' psychological health. Through a better understanding of such distressing experiences and their consequences, we may become better equipped to target NDE experiencers at high risk of developing long-lasting emotional trauma.

Regarding this study, it should also be noted that the cross-sectional and retrospective design could potentially represent a source of bias in the sense that narratives may have been tainted by widespread descriptions of NDEs in the media and in lay literature. Greyson (2007) however highlighted the consistency of NDE memories over a period of two decades. Additionally, since NDE experiencers voluntarily contacted our team, our sample might suffer from a self-selection bias and the proportion of distressing NDEs might not be genuinely representative. Overall, prospective data collection could constitute a way to address these issues.

To conclude, we confirmed Greyson and Bush's (1992) classification which includes inverse, void and hellish NDEs. NDE experiencers report similar ratings for the phenomenological details of distressing and classical NDE memories, which are both highly vivid. This work paves the way for research on the prevalence and consequences of distressing experiences. Frightening NDEs are under documented and require specific attention to be integrated into NDE experiencers' identity.

### 3 Near-death experience memories: Self-defining memories with flashbulb-like features?

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Based on the following publications:

**Cassol, H., D'Argembeau, A., Charland-Verville, V., Laureys, S.\*, & Martial, C\*** (contributed equally). (2019). Memories of near-death experiences: are they self-defining? *Neuroscience of Consciousness*, 5(1), 1-9.

**Cassol, H., Bonin, E. A. C., Bastin, C., Puttaert, N., Charland-Verville, V., Laureys, S., & Martial, C. (in preparation).** Near-death experience memories include more episodic and non-episodic components than flashbulb memories.

## 3.1 Study 3. Are near-death experience memories self-defining?

### 3.1.1 Summary

We assessed to what extent NDE memories are considered self-defining: memories that help people to define clearly how they see themselves. We screened 71 participants using the Greyson NDE scale (48 real NDE experiencers and 23 NDE-like experiencers who had lived a similar experience in absence of a threat to their life). Participants described their two main SDMs. For each SDM, they completed the Centrality of Event Scale (CES) to assess how central the event is to their identity. The two subgroups did not differ regarding the proportion of NDE experiencers who recalled their NDE (30 real NDE experiencers out of 48 and 11 NDE-like experiencers out of 23). Real NDE experiencers and NDE-like experiencers who recalled their NDE (n=41) reported richer experiences as assessed by the Greyson NDE scale. Furthermore, these participants rated their NDE memory as more central to their identity as compared to other SDMs, and the richness of the NDE memory was positively associated to its centrality (CES scores). Overall, these findings suggest that the self-defining aspect of the experience might be related to its phenomenological content rather than its circumstances of occurrence. The self-defining status of NDE memories confirms that they constitute an important part of NDE experiencers' personal identity and highlights the importance for clinicians to facilitate their integration within the self.

### 3.1.2 Introduction

Along with its particular circumstances of appearance and its mystical connotation, the NDE phenomenon seems to be characterized by a rich phenomenology and a sense of realness (Martial, Charland-Verville, Cassol, et al., 2017; Moore & Greyson, 2017). Consequently, NDEs appear to have short- and long-term consequences on people's lives (Greyson, 1997; van Lommel et al., 2001). Given their significance and consequentiality, NDE memories appear to share similarities with a particular type of autobiographical memories referred to as SDMs (Blagov & Singer, 2004).

SDMs are emotionally intense, vivid, and frequently recalled memories that reflect important themes and conflicts in a person's life (Singer & Salovey, 1993). These emotional memories are the building blocks of identity and contribute, in particular, to the sense of self-continuity (Conway, Singer, & Tagini, 2004), which relies on the ability to consider oneself as an entity that extends back into the past and forward into the future (Chandler, 1994). This ability is central to numerous processes such as planning future actions, giving meaning to new experiences or taking responsibility (Sani, 2008). SDMs can be characterized along four dimensions: (i) their specificity, which refers to the structure of the memory; (ii) the presence of meaning making, which reflects the individual's propensity to derive personal meaning and reflect upon the experience; (iii) their content, which makes reference to the primary concern of the experience; and (iv) the associated affect, which represents the emotions felt upon recall (see **Table 15** for a more detailed description; Blagov & Singer, 2004). From a clinical perspective, scholars have shown that the recall of emotionally positive SDMs as well as the ability to integrate a lesson or derive meaning from an experience are related to higher levels of psychological adjustments in healthy individuals (Blagov & Singer, 2004; Wood & Conway, 2006). Hence, careful consideration should be given to the development of these capacities of integration and autobiographical reasoning,

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especially when attempting to (re)build a sense of self-continuity (Inder et al., 2008). This integration process seems particularly important after intense life-threatening experiences such as NDEs.

**Table 15. The four dimensions of self-defining memories (SDMs) (Blagov & Singer, 2004; McLean & Fournier, 2008).**

DIMENSION	DESCRIPTION		
Specificity	<i>Specific</i>	<i>Non-specific</i>	
	<p><b>Specific memories</b> are characterized by uniqueness of occurrence and limited duration in time (&lt;24h). Example: <i>“The day I broke my leg during gym class in second grade”</i>.</p>	<p><b>Extended memories</b> include events that occurred over an extended period of time (&gt;24h). Example: <i>“My skiing holidays in Switzerland when I was 10 years old”</i>.</p>	<p><b>Generic memories</b> comprise events that occurred repeatedly over time. Example: <i>“The huge annual Christmas meals at grandma’s”</i>.</p>
<p><b>Autobiographical reasoning</b></p>	<p>Autobiographical reasoning is notably studied as a dimension of SDMs and consists in reflecting on the implications and the personal meaning of the event (Singer &amp; Bluck, 2001). This meaning making may relate to lesson learning and/or insight gaining (Thorne &amp; McLean, 2001).</p>		
<p><b>Event content</b></p>	<p>SDMs have been classified into 7 distinct categories (Thorne &amp; McLean, 2001):</p> <ol style="list-style-type: none"> <li>1. <i>Life-threatening</i> This category includes events with issues of life and death. The mentioned emotions are generally fear or sadness. These events may correspond to:               <ol style="list-style-type: none"> <li>a. Death or serious illness/injury of someone else</li> <li>b. Serious accidents or illnesses to oneself</li> <li>c. Physical assaults</li> <li>d. Rapes, attempted rapes, or sexual abuses to oneself</li> <li>e. Not classifiable</li> </ol> </li> <li>2. <i>Recreation/exploration</i> Narratives corresponding to this category center on recreational activities such as hobbies or travels.</li> <li>3. <i>Relationship</i> Relationship events comprise experiences in which interpersonal relationships are emphasized, such as a first love or a separation.</li> </ol>		

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	<ol style="list-style-type: none"> <li>4. <i>Achievement/mastery</i> This category groups events relating to arduous attempts at accomplishment, for example winning a competition, passing or failing an exam.</li> <li>5. <i>Guilt/shame</i> This subset of events includes memories focusing on notions of “doing right” vs. “doing wrong” (e.g., feeling guilty about lying or hurting someone).</li> <li>6. <i>Drug/alcohol abuse</i> Narratives classified in this category are centered on drugs, tobacco and alcohol, for recreational use as well as suicide attempts.</li> <li>7. <i>Not classifiable.</i> Not classifiable events refer to experiences that do not fit into any of the previous categories.</li> </ol>
<b>Affect</b>	This dimension corresponds to the affective response triggered by the retrieval of the memory (Blagov & Singer, 2004).

This study therefore seeks to determine if NDE memories may be considered as self-defining. First, because of their documented life-transforming effects and their reported importance (Greyson, 1997), we predicted that a majority of NDE experiencers would describe their NDE as one of their two main SDMs. To do so, they completed an online survey on their SDMs. In order to determine whether the potential self-defining dimension of NDEs is due to their phenomenal content or their circumstances of appearance (i.e., presence or absence of impending death), we also included a subgroup of NDE-like experience (i.e., people who experienced a NDE in absence of life threat). Second, we expected that NDEs memories would be considered as more central to NDE experiencers’ identity and life story as compared to the other recalled SDM. To test this hypothesis, the CES (Berntsen & Rubin, 2006), which assesses how central an event is to a person’s identity, was administered. We also looked at the association between the intensity of the NDE, as measured by the Greyson NDE scale developed to quantify the self-reported richness of the experience (Greyson, 1983), and its centrality to NDE experiencers’ selves. Finally, we explored the four dimensions of reported SDMs with a particular attention to meaning making and affect, which are crucial to psychological well-being.

### 3.1.3 Materials and Methods

#### 3.1.3.1 Participants

Participants were initially recruited following calls for NDE testimonies via the websites, the appearances in local media, and the publications of the IANDS and the Coma Science Group (GIGA-Consciousness, University and University Hospital of Liège, Belgium). People who contacted us to share a written narrative of their experience were mailed questionnaires including the Greyson NDE scale (Greyson, 1983), used to identify the presence of a NDE memory by assessing the presence of specific affective, cognitive, transcendental, and paranormal features. Additionally, they completed questionnaires requesting socio-demographic information (gender, age at interview, and religious belief at the time of the NDE—religious or nonreligious), their age when they experienced the NDE, the time elapsed since the NDE, and the circumstances of appearance of their NDE. On this basis, they were assigned to two subgroups: a “real NDE” subgroup (i.e., experiences equal or above the cut-off score of 7 that occurred following a severe brain injury accompanied by a period of coma >1 h and an hospitalization in an intensive care unit) or a “NDE-like” subgroup (i.e., similar phenomenological experiences equal or above the cut-off score of 7 that occurred in situations where there was no genuine threat to the individual’s life; Charland-Verville et al., 2014). Once the participants were divided into two subgroups, they were re-contacted and invited to participate in another study focusing on SDMs. The final study sample was composed of 48 individuals who reported having lived a “real NDE” and 23 individuals who described a “NDE-like”.

The study was approved and carried out in accordance with the recommendations of the ethics committee of the Faculty of Medicine of the University of Liège. All participants completed a written informed consent in accordance with the Declaration of Helsinki.



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### 3.1.3.2 Materials

#### 3.1.3.2.1 Self-defining memory task

Participants were invited to describe their two main SDMs. It was not specified whether or not one of them should be their NDE since we wanted to determine the proportion of NDE experiencers who would spontaneously mention their NDE as one of their main SDMs. All participants wrote down their two main SDMs in any order (i.e., without constraints regarding the chronology or the subjective importance of the recalled memories) and with no limit regarding the number of words. To do so, they received a written definition of a SDM: (i) the memory has to be at least 1-year-old (in order to better gauge the impact of an event, one has to have a sufficient hindsight regarding what he/she has experienced; it should be underlined that this criterion could not have impacted the number of NDEs recalled since all NDE experiencers had experienced their NDE more than one year before completing the survey); (ii) it has to be a very clear memory of an important event that was personally experienced; (iii) it helps understanding who one is as an individual; (iv) it relates to a personally significant and enduring theme or concern, and it is linked to other memories that share the same theme; (v) it generates strong feelings, no matter the valence; and (vi) it has been recalled a great number of times (adapted from Blagov & Singer, 2004; Singer & Moffitt, 1991–1992).

#### 3.1.3.2.2 Affect

Participants indicated on a 7-point Likert scale ranging from -3 (very negative) to +3 (very positive): (i) emotions felt during the event and (ii) emotions felt while remembering the event and thinking about its consequences on their lives (questions derived from the validated Memory Characteristic Questionnaire; Johnson et al., 1988).

### 3.1.3.2.3 Centrality of event scale

This instrument measures how central an event is to a person's identity and life story, with 20 items rated on a 5-point scale (from 1= totally disagree to 5 = totally agree). Items 1, 2, 4, 9, 12, 13, 17, and 20 have been developed to assess whether an event has become a reference point for the generation of expectations and attribution of meaning to other events in one's life story. Items 3, 5, 6, 7, 8, 11 and 19 were designed to assess whether an event is considered as a central component of the person's identity. Finally, items 10, 14, 15, 16, and 18 address whether the event is considered by the respondent as a turning point in his/her life story (Berntsen & Rubin, 2006).

### 3.1.3.3 Procedure

After initial recruitment (see Participants section), participants of both subgroups ("real NDE" and "NDE-like") were invited to participate in a study on SDMs. They received an email with a link to an online survey: (i) they completed an online consent form including a description of the study; (ii) they answered items related to socio-demographic data; (iii) they completed the SDM task; (iv) finally, for each of their two SDMs, they rated the associated affect and completed the CES. The order of rating of the two SDMs was randomized: part of the participants rated the first recalled SDM as a first step and then the second recalled SDM, while the other participants rated their SDMs in the reverse order. The order of SDM rating was randomized to circumvent a possible bias: we assumed that most participants would recall their NDE memory first and we wanted to minimize possible order effects in describing and assessing SDMs.

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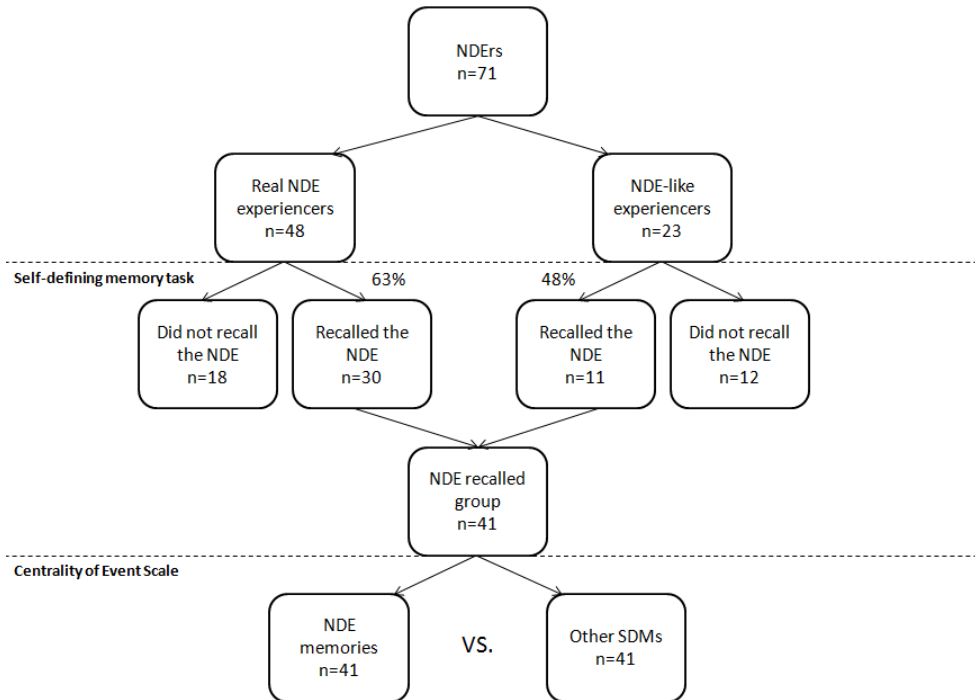
#### 3.1.3.4 Analyses

Results were considered to be significant at an alpha of 0.05 and were expressed as mean  $\pm$  SD for normally distributed quantitative variables and as median (IQR) for quantitative variables with a skewed distribution. Categorical variables were expressed as counts and proportions (%). Data analyses were carried out using R statistical software (R 3.4.1).

##### 3.1.3.4.1 Demographics and questionnaires

As a first step, we compared the gender and religious beliefs ratios between “real NDEs” and “NDEs-like” by means of a Fisher’s exact test with contingency tables. Student’s t-tests were used to compare reported intensity of the NDE (Greyson NDE scale total scores), age at NDE, and age at interview between subgroups. Distributions being skewed, differences for time since NDE were analyzed using Wilcoxon–Mann–Whitney U tests. Finally, percentages of NDE experiencers who recalled their NDE were calculated for each subgroup and a Fisher’s exact test was performed to compare ratios between subgroups. As a second step, all participants were divided into two subgroups depending on whether or not they recalled their NDE (no matter its context of occurrence). We compared the gender ratio between the “NDE recalled” and the “NDE not recalled” subgroups with a Fisher’s exact test. Intensity of the NDE (Greyson NDE total scores), age at NDE, age at interview and time since NDE were compared by means of Student’s t-tests. **Figure 4** represents the flowchart of the distribution of NDE experiencers within the different subgroups.

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**Figure 4** – Flowchart representing the distribution of participants within the different subgroups.

#### 3.1.3.4.2 Dimensions of self-defining memories

First, we examined the centrality of events for identity and life story (as assessed by the CES scale) in the “NDE recalled” subgroup. Differences in CES total scores between the NDE memory and the other SDM were assessed using a Student’s t-test. Next, we examined associative strength between CES and Greyson NDE scale total scores for the NDE memories using a Spearman’s correlation. Second, ratings of affect were compared between NDE memories and other SDMs, using a Wilcoxon–Mann–Whitney U test. Third, two coders (HC and CM) scored the four dimensions of all reported SDMs (n=142). The specificity of each SDM was classified in three categories: (i) specific events that happened in a particular time and place and lasted less than 24 h; (ii) extended events that lasted longer than a

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day; and (iii) generic events that occurred repeatedly. The number of observed agreements was 138 out of 142 (97.18%), which corresponds to a Cohen's kappa coefficient of 0.89 (95% confidence intervals 0.79–1). The presence (score of 1) or absence (score of 0) of meaning making in each narrative was also determined. The number of observed agreements was 135 out of 142 reported SDM narratives (95%), which corresponds to a Cohen's kappa coefficient of 0.90 (95% confidence intervals 0.83–0.97). To examine whether NDE memories differed from the other SDMs in terms of meaning making, a Pearson's chi-squared test was used to assess frequency distribution of meaning making among the two types of memories. Finally, coders proceeded to the rating of the content of SDMs based on the classification proposed by Thorne and McLean (2001). This classification includes seven major categories: (i) life-threatening events, (ii) recreation/exploration, (iii) relationship, (iv) achievement/mastery (either with positive or negative outcomes), (v) guilt/shame, (vi) drug/alcohol abuse, and (vii) "not classifiable". Additionally, a subclassification of life-threatening events was used, as suggested by Thorne and McLean (2001): (a) death or serious illness/injury of someone else (person or animal), (b) serious accidents or illnesses of oneself, (c) physical assault, (d) rape, attempted rape, or sexual abuse (to oneself), (e) "not classifiable" life-threatening events. The number of observed agreements for all SDMs was 135 out of 142 (95% of the observations), which corresponds to a Cohen's kappa coefficient of 0.94 (95% confidence intervals 0.90–0.98). For all dimensions, discrepancies between raters were discussed in order to reach a final classification of all the narratives.

### 3.1.4 Results

#### 3.1.4.1 Demographics and questionnaires

The “real NDE” subgroup (n=48) included NDEs that occurred following a life-threatening situation such as anoxia (e.g., cardiac arrest, near-drowning; n=19), trauma (e.g., motor vehicle accident, falls; n=14), and other events (non-traumatic events such as complication during surgery; n=15). The “NDE-like” subgroup (n=23) included NDEs that occurred following a non life-threatening event such as sleep (n=5), syncope (n=5), drug and alcohol consumption, (n=3) or other non-life-threatening situations (e.g., grief, migraine; n=10). No significant differences were found between “real NDEs” and “NDEs-like” in terms of gender, Greyson NDE total scores, age at NDE, age at interview, and time since NDE (see **Table 16**).

Overall, 58% of the total sample recalled the NDE as one of their two main SDMs (41 participants out of 71), respectively 30 NDE experiencers out of 48 in the “real NDE” subgroup vs. 11 NDE experiencers out of 23 in the “NDE-like” subgroup. The Fisher’s exact test did not show a significant difference between subgroups regarding the ratio of participants recalling the experience ( $p=0.307$ ;  $\phi=-0.139$ ). “NDE recalled” and “NDE not recalled” subgroups did not significantly differ in regard to gender, age at NDE, age at interview and time since NDE. In contrast the “NDE recalled” subgroup showed higher total scores on the Greyson NDE scale (see **Table 16**).

**Table 16. NDE experiencers' Greyson total scores and demographic characteristics (n=71).**

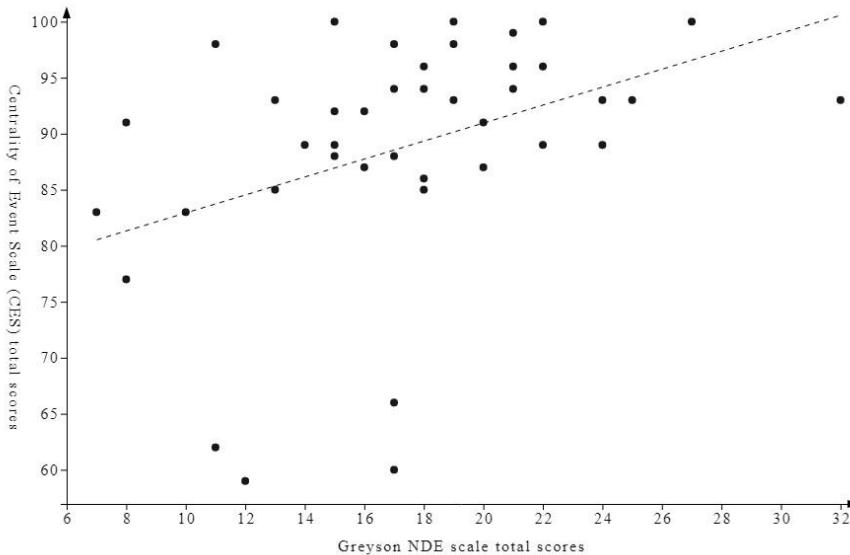
	Real NDE (n=48)	NDE-like (n=23)	<i>p</i> -value	Effect size	NDE recalled (n=41)	NDE not recalled (n=30)	<i>p</i> -value	Effect size
Gender –female(%)	32(67)	18(78)	0.317	0.119 <sup>‡</sup>	28(63)	22(73)	0.646	0.055 <sup>‡</sup>
Religious(%)	35(73)	14(61)	0.411	-0.122 <sup>‡</sup>	<b>33(80)</b>	<b>16(53)</b>	<b>0.019</b>	<b>-0.29<sup>‡</sup></b>
Greyson total score	17(5)	15(5)	0.124	-0.4	<b>17(5)</b>	<b>14(5)</b>	<b>0.008</b>	<b>-0.6</b>
Age at NDE	28(16)	34(17)	0.207	0.368	28(19)	33(19)	0.199	0.263
Age at interview	57(14)	59(11)	0.558	0.152	57(14)	58(12)	0.635	0.076
Time since NDE in years	31(12-41)*	26(10-38)*	0.376	-0.106 <sup>+</sup>	29(16)	25(17)	0.365	-0.243

Quantitative variables are summarized using the *M(SD)*, except for data with \* representing median (IQR). The effect size is expressed as  $G_{Hedges}$ , except for data with <sup>‡</sup> which are expressed as  $\phi$  and data with <sup>+</sup> which is expressed as *r*. Results in bold are significant.

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#### 3.1.4.2 Dimensions of self-defining memories

Analysis of the CES scores carried out on the “NDE recalled” subgroup (n=41; 30 real NDE experiencers and 11 NDE-like experiencers) showed that NDE memories received higher CES total scores (median=92, IQR=87–96) than other SDMs (median=75, IQR=59–84) ( $p<0.001$ ;  $r=-0.574$ ). Moreover, a significant positive correlation was found between CES scores for the NDE memory and Greyson NDE scale total scores ( $r_s=0.48$ ,  $p<0.001$ ; **Figure 5**).



**Figure 5** – Association between CES total scores for the NDE memory and Greyson NDE scale total scores within the NDE recalled subgroup ( $r_s=0.48$ ,  $p=0.001$ ).

Regarding affect, the analyses showed that emotions felt during the event were more positive for NDE memories (median=7, IQR=6–7) compared to other SDMs (median=4, IQR=1–6) ( $p<0.001$ ;  $r=-0.430$ ). Moreover, emotions felt upon



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recall were also considered more positive for NDE memories (median=7, IQR=6–7) compared to other SDMs (median=6, IQR=4–7) ( $p < 0.001$ ;  $r = -0.346$ ).

The classification of the specificity of all SDMs ( $n=142$ ) indicated that participants reported 122 specific SDMs (<24h; 86%), 14 extended SDMs (>24h; 10%), and 6 generic SDMs (repeated events; 4%). All NDE memories were specific.

Meaning making was detected in 62 of the 142 SDMs (44%). The difference in ratio of meaning making between NDE memories (21 out of 41; 51%) and other SDMs (41 out of 101; 41%) was not statistically significant ( $p = 0.267$ ;  $\phi = 0.097$ ).

Finally, regarding memory content, NDEs recalled by real NDE experiencers ( $n=30$ ) were all classified as serious accidents or illnesses to oneself (despite containing additional transcendental and paranormal components as compared to other life-threatening events, as assessed by the Greyson NDE scale) and NDEs recalled by NDE-like experiencers were classified as exploration events (i.e., experiencing an unexpected spiritual moment;  $n=10$ ) or events relating to drug use ( $n=1$ ). The classification of all reported SDMs (including NDEs and NDEs-like;  $n=142$ ) consisted of 68 memories of life-threatening events (48%), 30 memories relating to relationships (21%; e.g., life-changing encounter, child birth, or family/friend reunion after a long separation), 19 memories centered on exploration (13%; e.g., facing personal challenges), 18 memories that emphasize achievement (13%; e.g., professional recognition and promotion or difficult child birth), and 3 memories about feelings of guilt/shame (2%), 3 unclassifiable events (2%), and 1 event relating to drug use (1%). Subclassification of the 68 life-threatening events included 42 events of serious accidents or illnesses to oneself (62%; e.g., learning to live in an handicapped body after severe accident or survival during times of war), 18 events of deaths or serious illnesses/injuries of someone else (26%; e.g., death in the family or illness of a child), 7 events relating to physical assault (10%; e.g., domestic violence), and 1 unclassifiable event (2%). The distribution of the 142 memories within the seven main categories is presented in **Figure 6**.

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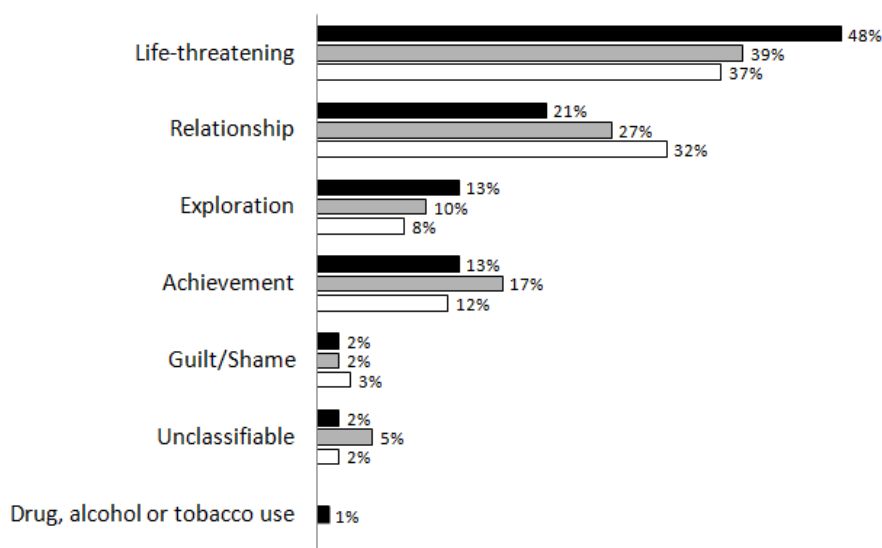
Overall, when examining the number of participants who recalled each type of content, we found that NDE memories constituted by far the most important category, as they were recalled by 41 participants (58% of the participants). The second most frequently reported subcategory of event was the “death of a family member” which was reported by 18% of participants (n=13), followed by a “life-changing encounter” (n=7; 10%), “domestic violence” (n=6; 8%), “family/friend reunion after a long separation” (n=5; 7%), and “learning to live in an handicapped body after severe accident”, and “confrontational relationships” (both reported by four participants; 6%). “Academic success,” “child births,” “facing personal challenges,” and “forced exile during times of war” were each reported by three participants (4%). “Difficult child birth,” “getting out of a depression,” “illness of a child,” “moment of extreme shame,” “physical assault” (as an aggressor), and “professional promotions” were each reported by two participants (3%).

The distribution of the other (non-NDE) SDMs (n=41) reported by the “NDE recalled” subgroup (i.e., real NDE experiencers and NDE-like experiencers who recalled their NDE as one of their two main SDMs) among the 7 major categories included 16 life-threatening events (39%), 11 events relating to relationships (27%), 7 events that emphasize achievement (17%), 4 events centered on exploration (10%), 2 unclassifiable events (5%), and 1 event relating to guilt/shame (2%). The drug, alcohol, and tobacco use category was not represented in this subgroup. Subclassification of the 16 life-threatening events included 7 events of serious accidents or illnesses to oneself (44%), 6 events of deaths or serious illnesses/injuries of someone else (37%), and 3 events relating to physical assault (19%). The other subcategories were not represented in the subgroup (see **Figure 6**).

Lastly, the distribution of the SDMs (n=60) reported by the “NDE not recalled” subgroup (i.e., real NDE experiencers and NDE-like experiencers who did not recall their NDE as one of their two main SDMs). This classification comprised

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22 life-threatening events (37%), 19 events relating to relationships (32%), 7 events that emphasize achievement (12%), 5 events centered on exploration (8%), 2 events relating to guilt/shame (3%), and 1 unclassifiable event (2%). The drug, alcohol, and tobacco use category was not represented in this subgroup. Subclassification of the 22 life-threatening events included 12 events of deaths or serious illnesses/injuries of someone else (55%), 5 events of serious accidents or illnesses to oneself (23%), 4 events relating to physical assault (18%), and 1 unclassifiable event (4%). The other subcategories were not represented in the subgroup (see **Figure 6**).



**Figure 6 – Classification of self-defining memories (SDMs) within the major event categories proposed by Thorne and McLean (2001).** In black: distribution of all reported SDMs (n=142). In grey: distribution of the other (non-NDE) SDM in the “NDE recalled” subgroup (n=41). In white: distribution of the SDMs in the “NDE not recalled” subgroup (n=60).

### 3.1.5 Discussion

This study investigated whether the memory of a NDE is considered as self-defining. Furthermore, to disentangle between the roles of the nature of the experience and its circumstances of appearance, real NDE experiencers (i.e., presence of a life-threatening event) and NDE-like experiencers (i.e. absence of life threat) described their two most significant SDMs. In line with our hypothesis, 58% of the entire sample recalled their NDE as a SDM, respectively 63% of real NDE experiencers and 48% of NDE-like experiencers. Analyses did not show significant differences in proportions between subgroups. Moreover, when looking closely at the content of NDEs, results indicated that NDE experiencers who selected their NDE as a SDM had lived richer experiences, as measured by the Greyson NDE scale (Greyson, 1983). Indeed, it is likely that NDEs with more cognitive, affective, transcendental, and/or paranormal characteristics are experienced more intensely, leading to memories that are more likely to be considered self-defining. Additionally, we found a larger proportion of religious NDE experiencers among participants who recalled their NDE. A possible explanation for this latter finding is that the NDE experience might be perceived as more meaningful for religious NDE experiencers, thus being more likely to be part of their identity. Overall, our results suggest that the self-defining aspect of the NDE memory could be related to its particular phenomenological content rather than its circumstances of occurrence, although future studies are required to clarify/confirm this latter point. Altogether, these results support the view that NDE memories constitute an important part of NDE experiencers' personal identity and are self-defining. This proposition is also consistent with previous results showing that two-thirds of those who experienced a NDE during a close brush with death describe a substantial impact of this experience on their lives (Noyes, 1980). Yet, it has to be borne in mind that the fact that some NDE experiencers did not recall their NDE does not necessarily mean that this experience is not considered self-defining. Indeed, most people can

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generally recall more than two SDMs and it might be that a higher proportion of NDE experiencers would recall their NDE if they were asked to recount more than two SDMs.

When considering participants who reported their NDE, we found a significant difference between the NDE memory and their other SDM regarding the CES total scores, the memory of the NDE being rated as more central to NDE experiencers' identities. Our results therefore suggest that NDE memories can be regarded as cornerstones in NDE experiencers' lives and that they might color the way they understand other experiences or the hardship in their lives. Additionally, richer (in terms of the number of reported features) NDEs were considered as more central to NDE experiencers' selves. Although this correlation does not demonstrate causality, it is reasonable to hypothesize that richer NDEs may lead to a memory that is more central to the person's identity. Considering that the richness of the experience appears to be associated with NDE experiencers' traits (e.g., fantasy proneness; (Martial et al., 2018), future studies should investigate to what extent NDE richness might also influence their interpretation and integration into the life story.

When taking a closer look at the dimensions of memories, we found that SDMs were globally pleasant and that NDE memories, in particular, were associated with positive affect upon recall. These results are consistent with the view that NDEs are typically associated with highly positive emotions (Greyson, 1983). Regarding the specificity of reported SDMs, we observed that a large majority of memories (86%) involved specific events rather than extended or generic events. This high percentage can be partly explained by the fact that life-threatening events are typically specific. Lardi, D'Argembeau, Chanal, Ghisletta, and Van der Linden (2010) have indeed highlighted that life-threatening events were the most specific memories, but they also noted that these events were typically associated with low positive affect and strong negative affect. Therefore, real NDEs

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seem to be a particular subtype of specific life-threatening events that has the particularity to be associated with positive affects upon recall.

Concerning memory content, half of the sampled memories referred to life-threatening events. The second most frequent type of memories were those in which interpersonal relationships are emphasized, followed by memories of events relating to exploration, memories highlighting effortful endeavor at mastery or accomplishment, and finally events encompassing guilt/shame and drug use themes. With the exception of life-threatening and exploration events that are unsurprisingly frequent in our sample given NDEs and NDEs-like events, the distribution of SDMs into the different categories is similar to some other studies in which memories relating to relationships and achievement concerns were largely represented (e.g., Lardi et al., 2010). In this context, it should also be emphasized that real NDEs memories appear as a unique and specific subtype of “serious accidents or illnesses to oneself” as they comprise distinguishable affective, cognitive, transcendental, and paranormal features, as compared to other events belonging to this subcategory.

In regard to meaning making, it is interesting to note that a majority of SDM narratives did not include meaning making (i.e., 44% of all reported SDMs included meaning making). Additionally, the difference in the prevalence of meaning making between NDE memories (51%) and other SDMs (41%) did not reach significance, which might suggest that autobiographical reasoning could partly depend on the individual rather than on the type of memory (Rubin, Berntsen, Deffler, & Brodar, 2018). The relatively low proportion of meaning making for NDEs is somewhat surprising given that it is considered crucial for psychological adjustment; indeed, the ability to reflect upon one’s life experiences has been associated with higher levels of socio-emotional maturity and is developed in psychotherapy to improve introspection abilities and build a unified self (Inder et al., 2008). Therefore, the development of psychological interventions

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aiming at facilitating the integration of NDEs into the sense of self and identity might be fruitful for some individuals who have experienced this impactful event.

Finally, some limitations of this study should be acknowledged. Given the relative scarcity of NDEs, we were limited in the recruitment of our participants and our sample is relatively small. Larger studies are therefore required to confirm these results. Besides, because NDE experiencers voluntarily contacted us, our sample suffers from a self-selection bias and one must bear in mind that, considering the mystical connotation of such experiences and the fact that they may be perceived as distressing, some people might feel uncomfortable to share these events. Another possible bias may have arisen from the fact that some participants might have guessed the objectives of the study and recalled their NDE accordingly or, on the contrary, might have felt that we wanted them to provide two memories other than their NDE. Nevertheless, after debriefing, no indication of this potential bias was observed. Finally, to exclude a possible influence of the context of events, future studies should also include a subgroup of individuals who have lived a close brush with death without experiencing a subjective NDE.

To conclude with this third study, the self-defining status of NDE memories reinforces the importance for caregivers to detect the presence of such an event in order to ensure, or at least facilitate, its later integration into NDE experiencers' selves. As a matter of fact, SDMs play a key role in the construction and maintenance of a coherent sense of self-continuity, which appears to be positively associated to psychological adjustment (Chandler, Lalonde, Sokol, & Hallett, 2003). Highly accessible and vivid personal memories contribute to the construction of life narratives and, in this way, enable the stabilization of the sense of self and identity (Baerger & McAdams, 1999). However, the outcome of this process is not systematically positive (Berntsen et al., 2003). A highly negative, unforeseen and relatively uncommon event might have an unfavorable influence on the interpretation of other experiences as well as on expectations about future events,

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and therefore can be harmful to mental health (Berntsen et al., 2003). Thereupon, it is reasonable to expect that atypical experiences of close brushes with death, such as NDEs, become reference points that could potentially lead to deleterious outcomes such as lower senses of self-continuity typically associated with anxiety and negative affect (Chandler et al., 2003). Overall, our study adds to the growing literature demonstrating the significant consequences of NDEs and highlights the fact that they deserve careful consideration.



Study 4. Near-death experience memories include more episodic and non-episodic components than flashbulb memories

## 3.2 Study 4. Near-death experience memories include more episodic and non-episodic components than flashbulb memories

### 3.2.1 Summary

NDE memories are recalled as "realer" than memories of real or imagined events. Given their rich phenomenology, emotionality and consequentiality, it was hypothesized that they could meet some aspects of the definition of flashbulb memories. We aimed to identify and compare the episodic and non-episodic information provided in verbal recollections of NDE, flashbulb and control autobiographical memories. The phenomenological characteristics and centrality of the memories were also compared. Twenty-five participants who had lived a NDE in a life-threatening situation were interviewed and completed the MCQ as well as the CES for their NDE, a flashbulb and another autobiographical memory used as control. Overall, transcribed NDE verbal recollections included more internal/episodic details than control autobiographical and flashbulb memories, and more external/non-episodic details than flashbulb memories. Moreover, flashbulb memories were associated to a lower intensity of feelings while remembering and a lower personal importance, and are less reactivated and less susceptible to be remembered from a first person perspective compared to NDE and control autobiographical memories. Finally, NDE memories are the most central memories to experiencers' identity, followed by control autobiographical and then by flashbulb memories. These findings corroborate previous studies highlighting the impact and uniqueness of NDE memories.

#### Study 4. Near-death experience memories include more episodic and non-episodic components than flashbulb memories

### 3.2.2 Introduction

Near-death experiences (NDEs) have been defined as psychological events usually occurring when people are close to death or in situations of intense danger (Greyson, 2000b). These mental/subjective experiences are known to contain some typical and recurrent features such as the vision of a bright light, OBEs or coming to a border or a point of no return (Cassol et al., 2018; Greyson, 1983; Martial, Cassol, Antonopoulos et al., 2017). Long regarded as taboo and out of reach for science, the scientific study of the phenomenon has emerged a little more than four decades ago and led to an increasing number of empirical research (e.g., Martial et al., 2019; Palmieri et al., 2014; van Lommel, Van Wees, Meyers, & Elfferich, 2001). NDEs are of particular clinical relevance given their frequency of appearance (between 6 and 23% of cardiac arrest survivors; (Greyson, 2003; Schwaninger et al., 2002; van Lommel et al. , 2001) and their consequences on NDE experiencers' lives (Cassol, D'Argembeau, Charland-Verville, Laureys, & Martial, 2019; Groth-Marnat & Summers, 1998). Numerous aftereffects have been reported, such as the development of a higher spirituality, less materialistic values or a reduced fear of death (Groth-Marnat & Summers, 1998; Knoblauch et al., 2001; Noyes, 1980).

Previous studies have highlighted the uniqueness of NDE memories within autobiographical memory (i.e., memories about an individual's life; (Williams et al., 2008). NDE memories were found to contain more details (e.g., sensory, emotional and self-referential) than memories of other real and imagined events, and memories of a period of coma or impaired consciousness following an acquired severe brain dysfunction without NDE (Thonnard et al., 2013). Thus, it was suggested that they could not be considered as imagined event memories. Other studies have found that richer NDEs (i.e., containing a larger amount of typical features, such as out-of-body experiences, entering an unearthly realm or an altered time perception) led to memories with more perceptual information such as colors, smells and sounds, more contextual information such as time and place,

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and more emotional information, as measured by the MCQ (Johnson et al., 1988; Martial, Charland-Verville, Cassol, et al., 2017; Moore & Greyson, 2017). At first sight, the important amount of phenomenological details contained in their recollections might seem counter-intuitive given that NDEs are assumed to occur during an altered state of consciousness and classically associated with a critical or confused situation (e.g., van Lommel et al., 2001). In an effort to explain the special nature of NDE memories, different theories have been put forth. Notably, it was suggested that the significant emotionality associated with these mental events could enhance the quantity of sensory details stored in memory (Schaefer & Philippot, 2005). Besides, emotional events are more likely to be frequently rehearsed, therefore potentially increasing the amount of memorized characteristics (Thonnard et al., 2013).

Given their emotionality and consequentiality (i.e., the consequences of the event for the individual or aftermath), some authors hypothesized that NDE memories could meet some aspects of the definition of a particular kind of autobiographical memories known as flashbulb memories (Thonnard et al., 2013). Flashbulb memories refer to very vivid and long-lasting memories of the circumstances in which one learned about a shocking public event (Brown & Kulik, 1977). Studies on flashbulb memories have been focusing on landmark events such as the September 11 terrorist attacks or the death/assassination of famous people (Curci et al., 2001; Finkenauer, Luminet, Gisle, El-Ahmadi, & Der, 1998; Tinti, Schmidt, Sotgiu, Testa, & Curci, 2009). A prominent feature of these memories is that they display high ratings of belief in accuracy/subjective certainty (Brown & Kulik, 1977; Kraha & Boals, 2014) and that people can usually remember some of their personal aspects for several decades (Berntsen & Thomsen, 2005), for example the place they were when they heard the news, who they were with, the clothes they were wearing, or the emotions felt at the time of the event (Luminet & Curci, 2009). Overall, details contained in flashbulb memories may fall into different “canonical” categories: place, ongoing activity, informant, own affect, other affect,

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and aftermath (Brown & Kulik, 1977). The level of consequentiality associated with flashbulb memories and the underlying memory processes however remain debated. Pioneers in the area have suggested that these memories do not imply the existence of a special memory mechanism and included the notion of consequentiality as a key element in the formation of these memories, along with novelty, surprise, emotionality and overt rehearsal (i.e., overt rehearsal takes place during conversations, contrary to covert rehearsal which takes place when the person thinks about the event; (Brown & Kulik, 1977; Finkenauer et al., 1998). However, results from other studies suggest different underlying memory processes for memories of learning about public news (such as flashbulb memories) and memories for private events (i.e., first-hand experience) (Demiray & Freund, 2015; Lanciano, Curci, Matera, & Sartori, 2018; Tinti et al., 2009). For example, first-hand experiences would show a higher consequentiality and life impact, and would have a protective function because their content is related to individual's personal identity and well-being (Pillemer, 2009).

Generally speaking, narratives of autobiographical memories are known to be multifaceted in content and to include both episodic (i.e., thoughts, emotions, information relating to time and place, as well as perceptual details) and semantic information (i.e., general knowledge and facts about the world and personal life) (Addis, Musicaro, Pan, & Schacter, 2010; Addis, Wong, & Schacter, 2008; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). Given that episodic and semantic memory are thought to rely on different neural processes (Moscovitch et al., 2005), Levine et al. (2002) have developed an Autobiographical Memory Interview (AI) which includes a reliable coding scheme enabling the distinction between episodic and non-episodic details comprised in verbalized autobiographical memories. In their AI coding scheme, episodic details (scored by using categories adapted from the MCQ) refer to the central event, as well as emotional, perceptual, temporal and spatial characteristics, and non-episodic details relate to repetitions, metacognitive statements, and information that does not pertain to the main event or that is not

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contextually bounded, such as general knowledge or facts. While the former seem essential for high-fidelity representation of personally experienced events, the latter rather contribute to the coherence and continuity of self-knowledge and identity through time (Levine et al., 2002). To date, the AI scoring scheme has been used in a wide range of studies related to memory processes in ageing (e.g., Levine et al., 2002), psychiatric conditions (e.g., Moscovitch et al., 2018), neurodegeneration (e.g., Bastin et al., 2013) or lesion cases (e.g., Steinworth, Levine, & Corkin, 2005). However, no study has yet investigated the episodic and semantic composition of NDE verbal recollections to compare them with those of flashbulb memories. Therefore, the primary aim of this study was to (1) assess whether the episodic and non-episodic information comprised in verbal recollections of NDE, flashbulb and control autobiographical memories differ and (2) further compare their phenomenological characteristics using the sMCQ (a short version of the MCQ (D'Argembeau & Van der Linden, 2008; Johnson et al., 1988) and their consequentiality by means of the CES (Berntsen & Rubin, 2006).

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### 3.2.3 Materials and Methods

#### 3.2.3.1 Participants

NDE experiencers were recruited via the websites, appearances in local media and publications of the IANDS France, the Coma Science Group (University Hospital of Liège, Belgium), and the GIGA-Consciousness (University of Liège, Belgium). The study was approved by the ethics committee of the Faculty of Medicine of the University of Liège. Participants who contacted us signed a written consent form, completed questionnaires requesting socio-demographic (gender and age at interview) as well as clinical information (age at the NDE, time elapsed since the NDE and presence of a life threatening event), and completed the Greyson NDE scale (Greyson, 1983). We included in the present study 25 participants whose experience was secondary to a life-threatening situation and who met the accepted criteria of a NDE (i.e., Greyson NDE scale's total score  $\geq 7$ ).

#### 3.2.3.2 Experimental task

We conducted a semi-structured interview in a quiet room for each participant. As a first step, we administered a screening assessment including the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) and the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), in order to detect and exclude memory biases related to negative mood as well as mild cognitive impairments, respectively. Once participants were screened for mood and for memory impairments, the interviews were carried out based on the probing and scoring recommendations of the AI by Levine and colleagues (Levine et al., 2002).

Specifically, participants were asked to freely describe in considerable detail three target memories dating (without restriction regarding the recall time),

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as far as possible, to the same period: (1) the memory of their NDE, (2) a flashbulb memory (they were provided with a definition and examples; i.e., memories for the circumstances in which one first learned of a very surprising and consequential or emotionally arousing event such as September 11 terrorist attacks), and (3) an autobiographical memory. Each event had to be temporally and contextually specific, occurring over minutes or hours, but not exceeding a day. The order in which the memories were to be recalled was randomized. According to the AI guidelines, two further levels of recall may be needed in case of a lack of key information: (1) general and (2) specific probing. General probes are non-specific cues aiming to encourage full description (e.g., "Can you tell me more about it?"). Specific probes cue precise aspects of the event in order to determine if participants remember more information (e.g., "Where did this event take place?"). Nevertheless, no specific probe was employed in the present study due to substantial recalls by our participants. Narratives were audio-recorded, transcribed and analyzed using the established manual scoring procedure, allowing to separate episodic details (i.e., description of the event, sensory or mental state details specific to the event; "internal details") from non-episodic details (i.e., semantic or factual statements, or other details not specific to the event; "external details") (Levine et al., 2002).

Finally, after each memory recall, participants completed the short version of the Memory Characteristics Questionnaire (sMCQ; D'Argembeau & Van der Linden, 2008; adapted from Johnson et al., 1988) and the CES (Berntsen & Rubin, 2006).

#### 3.2.3.3 Analysis

Data analyses were carried out using R statistical software (R 3.5.2).

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### 3.2.3.4 Study sample

Greyson NDE scale total scores, age at NDE and age at interview are summarized as mean  $\pm$  SD. Distributions being skewed, results at the PANAS and the MoCA are summarized as median (IQR), and differences for time since event (NDE vs. flashbulb vs. autobiographical) were analyzed using Friedman tests and expressed as median (IQR) and average rank.

### 3.2.3.5 Autobiographical Memory Interview

The transcribed recalls were segmented into “details”, or “segments”. A detail is defined as « a unique occurrence, observation, or thought, generally expressed as a grammatical clause » (Levine et al., 2002). A segment can be defined as a sentence or part of a sentence that conveys information. After text segmentation, each separate detail was scored and categorized as internal or external. Internal details pertain to the main event and are episodic in nature, whereas external details are not directly related to the main event and may correspond to semantic information. Internal details are subdivided into: (1) event details, which describe the unfolding of the story (e.g., happenings, persons involved, reactions/emotions of oneself or other people, one’s clothing, the weather); (2) the time (e.g., life epoch, day, month, year, season, clock time); (3) the place (i.e., any information that involves localization in space, such as a city, a street, a building, a room); (4) perceptual details (i.e., visual, olfactory, tactile, gustatory, auditory information, proprioceptive or nociceptive information); and (5) thoughts and emotions (relating to the mental state of the subject). Apart from semantic information, repetitions of information and other unrelated details (i.e., time, place, event, perceptual and emotional details that do not directly pertain to the main event) are classified as external. Two independent raters (HC and EB) analyzed each transcribed recall by scoring each detail. Scoring reliability was



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assessed using intra-class correlation (ICC) coefficients, showing that both raters scored the narratives in a highly reliable manner ( $ICC_{\text{internal details}}: 0.99$ ;  $ICC_{\text{external details}}: 0.98$ ). Residual discrepancies between raters were discussed later on to reach a final classification for all details. Based on this final classification, all subtypes of details generated spontaneously were summed across memories.

For each type of memory, the main measures of interest were the overall amount of (1) internal details, (2) external details, and (3) the ratio of internal details to total details in order to assess the level of episodicity of the memories (i.e., the degree to which memories contain episodic details independently of the overall fluency of participants). Variables being normally distributed, differences between groups were assessed using one-way repeated measures analyses of variance (rmANOVAs) and results were considered significant at  $p=0.017$  after Bonferonni correction. In case of significant results, we performed post-hoc comparisons using Tukey HSD, setting the level of significance at 0.017 after Bonferonni correction. Regarding additional measures, we looked at the effect of the memory type on the amount of subtypes of internal and external memory details (i.e., event, perceptual, emotional and semantic details, as well as time, place and repetitions). Variables not being normally distributed, differences between groups were assessed using Friedman tests and results were considered significant at  $p=0.004$  after Bonferonni correction. In case of significant results, we performed post-hoc comparisons using Wilcoxon signed-rank tests, setting the level of significance at 0.017 after Bonferonni correction.

#### 3.2.3.6 Questionnaires

CES total scores were analyzed using a rmANOVA. Answers at the sMCQ being ordinal data measures, memories (NDE vs. flashbulb vs. autobiographical) were compared using a Friedman test, setting the level of significance at 0.003

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after Bonferonni correction. In case of significant results, we performed post-hoc comparisons using Tukey HSD tests for rmANOVAs and Wilcoxon signed-rank tests for Friedman tests, setting the level of significance at 0.017 after Bonferonni correction. Additionally, we examined associative strength between CES total scores and the reported details (i.e., internal score, external score, and internal ratio) using Pearson's correlations.

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### 3.2.4 Results

#### 3.2.4.1 Study sample

Our sample includes 25 NDE experiencers who have experienced a NDE following a life-threatening situation such as anoxia (e.g., cardiac arrest, near-drowning; n=8), trauma (e.g., motor vehicle accident, falls; n=6) or other events (non-traumatic events such as complication during surgery; n=11). Participants' negative mood was not higher than normal (i.e., as assessed by the PANAS) and they are all above the cut-off score at the MoCA (see **Table 17**).

All participants were able to recall a flashbulb memory and an autobiographical memory that happened around the same time than the NDE. Recalled memories do not differ regarding the number of years elapsed since the event (median<sub>NDE</sub>=27, IQR=10-45, average rank=2.24; median<sub>Flashbulb</sub>=17, IQR=15-27, average rank=1.68; median<sub>Autobiographical</sub>=26, IQR=12-42, average rank=2.08; [ $\chi^2(2)=4.622$ ,  $p=0.099$ , kendall coefficient=0.092]). Recalled flashbulb memories were the following: the assassination of J. F. Kennedy (n=1), the first steps on the moon (n=5), the fall of the Berlin wall (n=2), death of King Baudouin of Belgium (n=3), death of Princess Diana (n=1), September 11 terrorist attacks (n=8), Liège shooting attack (n=4) and Paris terrorist attacks (n=1). Demographical and clinical information of the entire sample can be found in **Table 17**.

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**Table 17. Demographic and clinical information for NDE experiencers (n=25; 10 female).**

Age at interview (in years)	
Mean ± SD	59±12
Age at NDE (in years)	
Mean ± SD	31±20
Reported time since NDE (in years)	
Mean ± SD	28±19
Greyson NDE scale total score	
Mean ± SD	15±5
PANAS+	
Median (IQR)	35(29-39)
PANAS-	
Median (IQR)	12(10-16)
MoCA	
Median (IQR)	29(28-30)

### 3.2.4.2 Autobiographical Memory Interview

The number of internal/episodic and external/non-episodic details and the ratio of internal details over the total number of details as a function of the type of memory are presented in **Table 18**. There was a significant main effect of the memory type on the quantity of reported internal/episodic details (see **Table 18**). Post-hoc comparisons indicated that the number of internal/episodic details for the NDE memory was significantly higher than for the autobiographical ( $F(1, 24)=29.343, p<0.001$ ) as well as for the flashbulb memory ( $F(1, 24)=34.906, p<0.001$ ). The autobiographical and the flashbulb memory did not differ ( $F(1, 24)=1.096, p=0.306$ ). We also found a significant main effect of the memory type on the amount of external/non-episodic details (see **Table 18**). Post-hoc comparisons indicated that the NDE memory contained significantly higher amount

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of external/non-episodic details than the flashbulb memory ( $F(1, 24)=13.368$ ,  $p=0.001$ ). However, the NDE and the autobiographical memory ( $F(1, 24)=6.154$ ,  $p=0.021$ ) did not differ. The autobiographical and the flashbulb memory did not differ either ( $F(1, 24)=1.173$ ,  $p=0.289$ ). Finally, the ratio of internal details did not differ between memories (see **Table 18**).

Differences in episodic and non-episodic subcomponents of NDE, flashbulb and autobiographical memories can be found in **Table 19**. Results indicated a main effect of the memory type on the amount of event and perceptual internal details (see **Table 19**). Specifically, post-hoc comparisons indicated that NDE memories contained significantly more internal event details than autobiographical ( $V=12$ ,  $p<0.001$ ) and flashbulb memories ( $V=19$ ,  $p<0.001$ ). Autobiographical and flashbulb memories did not differ ( $V=80$ ,  $p=0.223$ ). NDE memories also showed higher ratings for internal perceptual details as compared to autobiographical ( $V=3.5$ ,  $p<0.001$ ) and flashbulb memories ( $V=246$ ,  $p<0.001$ ). Once again, autobiographical and flashbulb memories did not differ ( $V=54.5$ ,  $p=0.775$ ). No other significant difference was observed. Although not significant when considering Bonferroni correction for multiple comparisons, there was a trend for higher emotional internal details associated with the NDE compared to other types of memories. To ensure our results are not due to the effect of confounding variables, we performed the analyses by integrating NDE experiencer's age as a regressor, which led to similar results.

**Table 18. Episodic/internal and non-episodic/external components of NDE, flashbulb and autobiographical memories.**

<b>AI details</b>	<b>NDE Mean(SD) n=25</b>	<b>Flashbulb Mean(SD) n=25</b>	<b>Autobiographical Mean(SD) n=25</b>	<b>F</b>	<b>Df1</b>	<b>Df2</b>	<b>p-value</b>	<b><math>\eta^2</math></b>
<b>Internal</b>	53(32.738)	15.96(8.899)	18.24(5.286)	30.337	2	48	<0.001*	0.558
<b>External</b>	19.76(14.615)	9.08(6.531)	11.44(10.198)	7.699	2	48	0.001*	0.243
<b>Ratio of internal details</b>	0.73(0.18)	0.64(0.16)	0.66(0.21)	2.060	2	48	0.139	0.079

Results are considered statistically significant at  $p < 0.017$  after Bonferroni correction. Df1=between groups degrees of freedom. Df2=within groups degrees of freedom. \*Results are significant.

**Table 19. Episodic/internal and non-episodic/external subcomponents of NDE (n=25), flashback (n=25) and autobiographical (n=25) memories.**

AI details	NDE Median(IQR)	NDE Average rank	Flashbulb Median(IQR)	Flashbulb Average rank	Autobio Median(IQR)	Autobio Average rank	$\chi^2$	Df	p-value	Kendall coefficient
<b>Internal</b>										
Event	20(9-33)	2.62	6(3-10)	1.50	10(4-12)	1.88	18.431	2	<0.004*	0.369
Time	2(1-3)	2.10	1(1-2)	1.64	2(1-3)	2.26	6.241	2	0.044	0.125
Place	1(0-2)	2.02	1(1-2)	2.18	1(0-2)	1.80	2.844	2	0.241	0.057
Perceptual	7(3-12)	2.76	0(0-2)	1.58	0(0-2)	1.66	27.175	2	<0.004*	0.544
Emotional	10(5-16)	2.48	3(2-6)	1.70	6(2-8)	1.82	9.800	2	0.007	0.196
<b>External</b>										
Event	7(1-13)	2.36	2(1-3)	1.62	3(1-6)	2.02	7.708	2	0.021	0.154
Time	0(0-0)	2.06	0(0-0)	2.00	0(0-0)	1.94	0.750	2	0.687	0.015
Place	0(0-0)	1.98	0(0-0)	1.96	0(0-0)	2.06	0.378	2	0.828	0.057
Perceptual	0(0-1)	2.16	0(0-0)	1.80	0(0-0)	2.04	7.000	2	0.030	0.140
Emotional	1(0-5)	2.16	1(0-2)	1.96	0(0-2)	1.88	1.489	2	0.476	0.030
Semantic	1(0-3)	1.98	3(1-4)	2.24	1(0-2)	1.78	3.325	2	0.190	0.067
Repetition	3(1-4)	2.32	2(1-2)	1.88	1(0-3)	1.80	4.722	2	0.094	0.094

Results are considered statistically significant at  $p < 0.004$  after Bonferroni correction. Df=degree of freedom. \*Results are significant.

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### 3.2.4.3 Questionnaires

#### 3.2.4.3.1 Short Memory Characteristics Questionnaire

Median ratings for each characteristic as a function of the type of memory are presented in **Table 20**. Results indicated a between-memory difference in the (1) feeling of mentally reliving the event, (2) sensation of feeling the emotions felt during the event while remembering, (3) visual perspective taken while remembering, (4) emotions felt at the time of the event (i.e., valence), (5) personal importance attached to the event, and (6) reactivation frequency. Memories did not differ in the amount of sensory details, clarity (i.e., time, location and coherence), confidence in the memory as well as remembering one's own actions/words/thoughts. Post-hoc comparisons indicated that the feeling of mentally reliving the event is higher in autobiographical memories as compared to flashbulb memories ( $V=187$ ,  $p=0.002$ ). NDE memories did not differ from autobiographical ( $V=32$ ,  $p=0.361$ ) and flashbulb memories ( $V=144$ ,  $p=0.049$ ). The sensation of feeling the emotions felt during the event while remembering is higher in NDE and autobiographical memories compared to flashbulb memories ( $V=192$ ,  $p=0.001$  and  $V=20$ ,  $p<0.001$ , respectively), but did not differ between NDE and autobiographical memories ( $V=37.5$ ,  $p=0.109$ ). Regarding visual perspective, flashbulb memories showed lower scores than NDE ( $V=162.5$ ,  $p<0.001$ ) and autobiographical memories ( $V=4.5$ ,  $p<0.001$ ) indicating that they were less susceptible to be remembered from a first person perspective. Difference between NDE and autobiographical memories did not reach significance ( $V=24$ ,  $p=0.438$ ). Flashbulb memories also showed lower scores for the valence as compared to NDE ( $V=207.5$ ,  $p<0.001$ ) and autobiographical memories ( $V=232$ ,  $p=0.001$ ; NDE and autobiographical memories did not differ,  $V=74.5$ ,  $p=0.171$ ), indicating that the latter were more positive in average. NDE and autobiographical memories also scored higher than flashbulb memories in terms of personal importance ( $V=250$ ,



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$p < 0.001$  and  $V = 7.5$ ,  $p < 0.001$ , respectively). On the other hand, difference between NDE and autobiographical memories did not reach significance ( $V = 30.5$ ,  $p = 0.307$ ). Finally, NDE and autobiographical memories were more frequently shared and reactivated than flashbulb memories ( $V = 211.5$ ,  $p < 0.001$  and  $V = 194$ ,  $p < 0.001$ , respectively). Once again, difference between NDE and autobiographical memories did not reach significance ( $V = 73.5$ ,  $p = 0.793$ ).

**Table 20. Score differences between NDE (n=25), flashbulb (n=25) and autobiographical (n=25) memories on the sMCQ.**

<b>sMCQ Items</b>	<b>NDE Median(IQR)</b>	<b>Average rank</b>	<b>Flashbulb Median(IQR)</b>	<b>Average rank</b>	<b>Autobio Median(IQR)</b>	<b>Average rank</b>	<b>X<sup>2</sup></b>	<b>Df</b>	<b>p-value</b>	<b>Kendall coeff.</b>
<b>Reexperiencing</b>	6(6-7)	2.20	5(3-6)	1.50	7(6-7)	2.30	12.500	2	0.002*	0.250
<b>Visual details</b>	7(6-7)	2.20	6(6-7)	1.76	7(6-7)	2.04	4.863	2	0.088	0.097
<b>Other sensory details</b>	6(5-7)	2.36	4(2-5)	1.60	6(4-7)	2.04	9.455	2	0.009	0.189
<b>Location</b>	7(7-7)	2.10	7(7-7)	2.02	7(6-7)	1.88	1.676	2	0.433	0.034
<b>Time</b>	4(1-6)	1.86	6(5-6)	2.32	5(2-6)	1.82	4.437	2	0.109	0.089
<b>Coherence</b>	7(7-7)	2.22	7(5-7)	1.72	7(6-7)	2.06	7.244	2	0.027	0.145
<b>Verbal component</b>	5(4-7)	2.12	5(4-6)	1.92	6(3-6)	1.96	0.903	2	0.637	0.018
<b>Feeling emotions</b>	6(5-7)	2.12	5(3-6)	1.48	7(6-7)	2.40	13.728	2	0.001*	0.275
<b>Real/imagined</b>	7(7-7)	2.08	7(7-7)	1.96	7(7-7)	1.96	1.200	2	0.548	0.024
<b>One's own actions</b>	7(6-7)	2.28	6(4-7)	1.58	7(6-7)	2.14	11.064	2	0.004	0.221
<b>One's own words</b>	7(5-7)	2.18	4(3-7)	1.80	6(4-7)	2.02	2.563	2	0.278	0.051
<b>One's own thoughts</b>	7(7-7)	2.38	6(4-7)	1.74	6(6-7)	1.88	8.448	2	0.015	0.169

<b>Visual perspective</b>	7(7-7)	2.28	5(1-6)	1.30	7(7-7)	2.42	27.382	2	<0.003*	0.548
<b>Valence</b>	7(6-7)	2.24	3(2-4)	1.24	7(6-7)	2.52	28.658	2	<0.003*	0.573
<b>Personal importance</b>	7(6-7)	2.42	3(2-4)	1.30	7(5-7)	2.28	22.707	2	<0.003*	0.454
<b>Reactivation frequency</b>	6(5-6)	2.38	3(2-4)	1.34	5(5-6)	2.28	20.835	2	<0.003*	0.416

Results are considered statistically significant at  $p < 0.003$  after Bonferroni correction. Df=degrees of freedom. \*Results are significant.

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### 3.2.4.3.2 Centrality of Event Scale

There was a significant effect of the memory type on the reported centrality [ $F(2, 48)=48.256, p<0.001, \eta^2=0.668$ ]. Post-hoc comparisons indicated that the mean score for the NDE memory (mean=81.4, SD=15.767) was significantly higher than the autobiographical memory (mean=62, SD=23.429) ( $F(1, 24)=12.767, p=0.002$ ) as well as the flashbulb memory (mean=35.36, SD=12.783) ( $F(1, 24)=115.525, p<0.001$ ). Moreover, the autobiographical memory was significantly higher than the flashbulb memory ( $F(1, 24)=38.149, p<0.001$ ). Additionally, a significant positive correlation was found between CES scores and the number of reported internal details ( $r=0.49, p<0.001$ ) as well as the number of external details ( $r=0.27, p=0.02$ ), regardless of the memory type. The correlation with the ratio of internal details did not reach significance ( $r=0.17, p=0.154$ ).

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### 3.2.5 Discussion

Previous studies have highlighted the vivid nature and high consequentiality of NDE memories (Cassol et al., 2019; Martial, Charland-Verville, Cassol, et al., 2017; Moore & Greyson, 2017; Thonnard et al., 2013), leading to the assumption that they could be underpinned by the same memory processes as flashbulb memories (Thonnard et al., 2013). Therefore, the aim of this study was to adopt a more fine-grained approach to highlight and compare the episodic and non-episodic contributions to the recall of NDE, flashbulb and control autobiographical events that occurred around the same time. To do so, we used the AI which provides reliable and valid indices of episodic and semantic contributions to personal remote memories.

First, analysis of verbal recollections highlighted that NDE memories include a higher amount of internal/episodic details than flashbulb and autobiographical memories, as well as more external/non-episodic information than flashbulb memories. This is consistent with previous studies suggesting a particularly high amount of qualitative characteristics associated with NDE memories in comparison with other types of memories (e.g., Moore & Greyson, 2017; Thonnard et al., 2013). In contrast, the internal detail ratio (i.e., the number of internal details produced in proportion of the total of details generated; also referred to as the “episodicity” of a memory) did not differ between memories. Interestingly, the higher amount of external details provided for NDE memories compared to flashbulb memories seemed to be driven by the recall of more specific details related to episodic events that were not the central NDE (rather than general semantic information). This would suggest that NDE memories also encompass vivid recall of surrounding events beyond the NDE itself.

The richness and high amount of overall details that have been delivered for NDE memories, as compared to other more or less notable memories dating

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from the same period, could be explained by various factors. First, a NDE itself is characterized by an exceptional and unique association between unusual perceptions (such as the impression of leaving the physical body, entering a different dimension or being in an unknown spatio-temporal dimension) and a clear sensorium and intense sensation of “reality” (i.e., comparable to the sense of certainty that accompanies everyday perception; Dell’Olio, 2010; Schwaninger et al., 2002), conditions that are likely to lead to vivid memories. Second, previous studies have highlighted a tendency towards a decline in memory reports (normal forgetting process) in flashbulb memories in comparison with other emotionally arousing events (e.g., Christianson, 1989; Christianson & Engelberg, 1999). Consistency and amplification of memories over time would be conditioned by one’s degree of involvement and the severity of the emotionally arousing event (Neisser et al., 1996; van Giezen, Arensman, Spinhoven, & Wolters, 2005). In line with this view, studies including participants who were directly exposed to or personally involved in traumatic events identified different memory patterns than studies addressing flashbulb memories, in which subjects were not personally involved in the emotional event. In fact, some studies have even shown that unlike the emotionally charged traumatic events whose narratives become richer over time, flashbulb memories rather tend to decline (Krinsley, Gallagher, Weathers, Kutter, & Kaloupek, 2003; van Giezen et al., 2005). When looking closer at the subtypes of details that have been recalled, we identified more event and perceptual internal details within the NDE memory, as compared to flashbulb and autobiographical memories. Specifically, event details describe the unfolding of the story, and perceptual details comprise auditory, olfactory, tactile, taste, visual and spatial-temporal (allocentric-egocentric space, body position and duration) information. Some authors suggested that the overall quantity of details comprised in NDE memories could be due to the fact that self-referential information can improve recalling performances (Conway & Dewhurst, 1995). Specifically, self-referential information would enhance the encoding process, the organization in

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memory, as well as the enrichment of the event by extended knowledge (Conway & Dewhurst, 1995). The high overall amount of phenomenological details in NDE memories could therefore be explained by the unprecedented nature of their emotions and features (Charland-Verville et al., 2014; Greyson & Stevenson, 1980; Greyson, 1983), as well as their self-defining value and high centrality to NDE experiencers' life stories, as reported by the CES (Berntsen & Rubin, 2006; Cassol et al., 2019). From a broader cognitive perspective, the high amount of internal/episodic and external/non-episodic details observed in verbal recollections of NDE memories is interesting as it suggests that people might be able to recall memories of a moment characterized by an altered state of consciousness where the brain and its associated processes are thought to be working with altered capacities. Nevertheless, it is still unclear when exactly these events are experienced as well as when their memory encoding precisely occurs.

Second, we compared the phenomenological characteristics (i.e., sMCQ scores) as well as the consequentiality and centrality (i.e., CES scores) of NDE, flashbulb and autobiographical memories. The analyses revealed that sMCQ scores related to NDEs and autobiographical memories were higher than those of flashbulb memories regarding the sensation of feeling the emotions felt during the event while remembering, their importance and their reactivation frequency. Moreover, the feeling of mentally reliving the event was higher for the autobiographical memory compared to the flashbulb memory. The finding that NDEs are emotionally highly charged and constitute an important part of NDE experiencers' life story is in line previous reports (e.g., Bianco, Sambin, & Palmieri, 2017; Cassol et al., 2019; Greyson, 1997). On the contrary, the high scores of autobiographical memories might seem unexpected but could find explanation in the fact that some of them were somewhat connected to the NDE. Indeed, NDE experiencers have lived their NDE several decades ago in average and reported difficulties when having to recall another event from the same period. From then on, recalled autobiographical memories were events closely linked to their

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NDE/coma (i.e., return to their daily lives after a long hospitalization, recovery after their coma) or significant/life-changing events such as a child birth or their encounter with their spouse (i.e., categories of memories that have typically been reported as self-defining in previous studies; e.g., Cassol et al., 2019). Furthermore, regarding reactivation frequency, it has been shown that shocking memories of personal events are more thought and talked about than news reception memories such as flashbulb events (Pillemer, 2009). Finally, we also noted significant differences regarding the perspective taken during recollection. Autobiographical memories can either be retrieved from the first person perspective, in which the experience is visualized through one's own eyes, or from the third person perspective, in which the experience is seen through an observer's eyes (Nigro & Neisser, 1983). While participants tended to see the scene from their own perspective (field perspective) when recalling their NDE and their autobiographical memory, it was less the case for flashbulb memories for which they were more likely to see themselves from an observer's perspective. Adopted visual perspectives are influenced by different variables and appear to be the consequence of contextual as well as dispositional factors, and/or their interaction (Nigro & Neisser, 1983; Sutin & Robins, 2008). These findings are consistent with previous research (Robinson & Swanson, 1993; Sutin & Robins, 2008) highlighting that natural first person memories are generally rated higher on the phenomenological dimensions related to the reliving of a memory. Moreover, it has been shown that the adoption of a third-person perspective could be an avoidance strategy set up to distance the individual from a memory and reduce its emotional intensity (Kenny & Bryant, 2007; Sutin & Robins, 2008). Therefore, the difference in the adopted visual perspective could be due to the emotions felt at the time of the event (i.e., valence), that are overall very positive in NDE as well as in autobiographical memories and more negative in case of flashbulb events. Regarding centrality, answers to the CES revealed that NDE memories had the higher scores, followed by autobiographical memories and then by flashbulb memories. These findings



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corroborate previous findings and confirm the particular status of NDEs with regard to NDE experiencers' identities and life stories (Cassol et al., 2019). The lower scores associated to flashbulb memories highlight the distinction between the consequences that one predicts when hearing about a surprising event and its actual impact on one's life. These results are consistent with previous research on hearing shocking public events that have shown lower life impact, consequentiality, and personal importance (Pillemer, 2009). In addition, we found that the amount of episodic and non-episodic details provided by participants was associated to their reported centrality, regardless of the memory type. It is therefore reasonable to hypothesize that central events could benefit from a preferential encoding in autobiographical memory.

Finally, we would like to mention limitations to this study. NDE experiencers voluntarily contacted us after calls in the lay media and our sample consequently suffers from a self-selection bias. Moreover, given the relative scarcity of NDEs and the fact that we had to meet participants personally in accordance to the AI protocol, we were limited in the recruitment of our participants and our sample is relatively small. Therefore, results should be confirmed by larger studies. Besides, human memory is by definition a reconstructive process (Schacter, Norman, & Koutstaal, 1998) sensitive to numerous factors such as ageing (e.g., Devitt, Addis, & Schacter, 2017); therefore, the generalizability of our results could also be impacted by the fact that all memories are drawn from a homogenous pool of NDE experiencers. To address this issue, it would be interesting to assess autobiographical and flashbulb memories in healthy controls and to further explore the cognitive processes specific to NDE experiencers, especially since previous studies suggest a specific cognitive profile, including a propensity for dissociation (Greyson, 2000a) and illusory recollections (Martial, Charland-Verville, Dehon, & Laureys, 2018).

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To conclude, we used the AI scoring protocol to explore the verbal content of three remote autobiographical memories in a sample of NDE experiencers: the NDE, a flashbulb and a control autobiographical memory. Overall, NDE verbal recollections include more internal/episodic than control autobiographical and flashbulb memories, and more external/non-episodic details than flashbulb memories. More precisely, they comprise more event and perceptual internal details. Moreover, we found that flashbulb memories are associated to a lower intensity of feelings while remembering and a lower personal importance, and are less reactivated and less susceptible to be remembered from a first person perspective. Finally, NDE memories are more central than autobiographical memories, which in turn are more central than flashbulb memories. Besides, more central events contain more episodic verbal details. Overall, our results fall in line with existing literature that highlights the uniqueness of NDE memories.

## 4 Neurochemical models of near-death experiences

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*Based on the following publication:*

**Cassol, H.\***, Martial, C.\* (contributed equally), Charland-Verville, V., Pallavicini, C., Sanz, C., Zamberlan, F., Vivot, R. M., Erowid, F., Erowid, E., Laureys, S., Greyson, B., & Tagliazucchi, E. (2019). Neurochemical models of near-death experiences: A large-scale study based on the semantic similarity of written reports. *Consciousness and Cognition*, 69, 52-69.

## 4.1 Study 5. A large scale study based on the semantic similarity of written reports

### 4.1.1 Summary

The real or perceived proximity to death often results in a non-ordinary state of consciousness characterized by phenomenological features such as the perception of leaving the body boundaries, feelings of peace, bliss and timelessness, life review, the sensation of traveling through a tunnel and an irreversible threshold. NDEs are comparable among individuals of different cultures, suggesting an underlying neurobiological mechanism. Anecdotal accounts of the similarity between NDEs and certain drug-induced altered states of consciousness prompted us to perform a large-scale comparative analysis of these experiences. After assessing the semantic similarity between  $\approx 15,000$  reports linked to the use of 165 psychoactive substances and 625 NDE narratives, we determined that the NMDA receptor antagonist ketamine consistently resulted in reports most similar to those associated with NDEs. Ketamine was followed by *Salvia divinorum* (a plant containing a potent and selective  $\kappa$  receptor agonist) and a series of serotonergic psychedelics, including the endogenous serotonin 2A receptor agonist DMT. This similarity was driven by semantic concepts related to consciousness of the self and the environment, but also by those associated with the therapeutic, ceremonial and religious aspects of drug use. Our analysis sheds light on the longstanding link between certain drugs and the experience of “dying”, suggests that ketamine could be used as a safe and reversible experimental model for NDE phenomenology, and supports the speculation that endogenous NMDA antagonists with neuroprotective properties may be released in the proximity of death.

## 4.1.2 Introduction

Throughout known history, humans have shown a tendency towards modifying their ordinary state of consciousness by consuming certain fungi and plant materials (Devereux, 1997; Escohotado, 1999). Naturally occurring molecules that interact with endogenous neurotransmitters and neuromodulators can induce an ample range of effects, such as sedation, stimulation, euphoria, modifications in the perception of the environment and the self, and complex and interactive hallucinations (Nichols, 2016). From Paleolithic cave art to contemporary music the ineffability of drug induced altered states of consciousness led to artistic expressions attempting to communicate the associated subjective experiences (Devereux, 1997; Shapiro, 1988). Frequently, analogies are made between the experiences elicited by certain psychoactive compounds and other non-ordinary states of consciousness (e.g., dreams, nightmares, sleep paralysis, mystical experiences, meditative states) (Kraehenmann, 2017; Millière, Carhart-Harris, Roseman, Trautwein, & Berkovich-Ohana, 2018; Sanz, Zamberlan, Erowid, Erowid, & Tagliazucchi, 2018). Certain psychiatric conditions have been compared (“modeled”) to the acute effects of psychoactive compounds (Bubeníková-Valešová, Horáček, Vrajová, & Höschl, 2008; Kyzar, Nichols, Gainetdinov, Nichols, & Kalueff, 2017; Nichols, 2016). Such comparisons are especially common for drugs collectively known as hallucinogens, a class that includes serotonergic psychedelics (the most known example being lysergic acid diethylamide [LSD]), dissociatives (e.g., arylcyclohexalamines such as ketamine and phencyclidine [PCP]) and deliriants (e.g., Solanaceae plants rich in anticholinergic tropane alkaloids). It is also documented that dopaminergic stimulants such as methamphetamine can induce psychotic hallucinatory states (McKetin, 2018).

Perhaps the most intriguing of all experiences compared to drug-induced altered states of consciousness is that of “death” or “dying” (Grof, Halifax, & Kübler-Ross, 1977; Strassman, 2001). Such comparison is evident in the etymology

Study 5. A large scale study based on the semantic similarity of written reports of word “ayahuasca” (“vine of the dead” in the Quechua language), an Amazonian concoction with psychedelic effects induced by DMT (Schultes & Raffauf, 2004). Certain societies indigenous to North America incorporate peyote (*Lophophora williamsii*, a cactus containing the psychedelic molecule mescaline) in their ceremonies to allow a glimpse into their conception of an afterlife (Bailey, 1973). The Bwiti people native to present-day Gabon employ the bark of Iboga (which contains the potent hallucinogenic tryptamine ibogaine) in combination with polyrhythmic music to induce “near-death” trances (Maas & Strubelt, 2003). In contemporary Western society, the experiences elicited by natural and semi-synthetic hallucinogens have also been compared to dying (Lee & Shlain, 1992). The feeling of death and rebirth attributed to certain psychedelics has been postulated as a component of their potential therapeutic effect (Grof et al., 1977). Descriptions of dissociative anesthetics, especially ketamine, abound in comparisons with the experience of dying (Corazza & Schifano, 2010; Jansen, 1990; Jansen, 1997a, 1997b). Timothy Leary, a key figure in the popularization and subsequent stigmatization of LSD, referred to ketamine experiences as “experiments in voluntary death” (Jansen, 1997a, 1997b). It must be noted that the comparison between the experiences induced by these drugs and dying occurs at a purely psychological level, since these substances are very safe under most circumstances (Alberich et al., 2017; Albott et al., 2018; dos Santos, Bouso, Alcázar-Córcoles, & Hallak, 2018; Nichols, 2016).

“Dying” as a non-ordinary state of consciousness can be related to NDEs (Greyson, 2008; Sleutjes et al., 2014). We have already discussed it, however, NDEs-like raise questions about the extent to which the proximity to death is involved in the appearance of a subjective NDE phenomenology. In addition, many researchers have independently noticed the phenomenological overlap between NDEs and the experiences induced by serotonergic and dissociative psychedelics (Jansen, 1990; Jansen, 1997a, 1997b; Strassman, 2001; Timmermann et al., 2018). Thus, it has been hypothesized that the long-standing association between these

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psychoactive compounds and the experience of “dying” could be based on their capacity to emulate NDEs.

The association between drug-induced experiences and NDEs is frequently discussed in terms of anecdotal evidence and firstperson accounts. Direct experimental evidence supporting this association is scarce. Corazza *et al.* retrospectively compared reports of 36 subjects who experienced NDEs (related to cardiac arrest) with the experiences of 36 subjects under the acute effects of ketamine (Corazza & Schifano, 2010). The authors found sufficient commonalities to conclude that ketamine can reproduce at least some aspects of NDE phenomenology. Recently, Timmermann and colleagues performed a within-subjects placebo-controlled study with 13 participants to test the phenomenological similarities between the DMT state and NDEs (Timmermann *et al.*, 2018). They found significant differences vs. placebo using numerical scales designed to quantify NDE (Greyson, 1983). Furthermore, the authors detected a significant overlap between the phenomenological features of DMT-induced experiences and those described by a matched group who reported a NDE after a life-threatening situation.

The aforementioned studies provide unique and valuable evidence, but also limitations related to the use of structured questionnaires to quantify and compare highly complex and heterogeneous experiences, as well as biases in the selection of the psychoactive compounds to be contrasted with NDEs. Indeed, NDE phenomenology has also been compared to that induced by LSD (Morse *et al.*, 1989), carbon dioxide (Meduna, 1950), hashish (Siegel, 1984), 5-MeO-DMT (the 5-methoxylated analogue of DMT) (Shulgin & Shulgin, 1997), ayahuasca (orally ingested DMT, enabled by its combination with  $\beta$ -carbolines present in *Banisteriopsis caapi*) (Strassman, 2001), and others. Thus, the following questions remain open: (1) Is the phenomenological similarity between NDEs and drug-induced experiences highest for substances within a certain pharmacological class

Study 5. A large scale study based on the semantic similarity of written reports

and mechanism of action?; (2) Can this similarity be inferred from unstructured free narratives, and do they offer insights complementary to the use of structured questionnaires?; (3) Given the heterogeneity in the events associated with NDEs (e.g., surrounding circumstances, proximity to death, emotional valence attributed by the subject, etc.), does such heterogeneity reflect on the similarity with the phenomenology of drug-induced states of consciousness?

In the present work we seek to provide an answer to these questions by retrospectively comparing 625 narratives of events classified as NDEs with a large number of reports (> 15,000) spanning experiences with 165 psychoactive substances of ten different pharmacological classes. We build upon previous work showing that natural language processing (NLP) tools used to obtain the semantic similarity between narratives provide an unstructured alternative to quantify the phenomenological similarity of different reported experiences (Lange, Greyson, & Houran, 2015; Sanz et al., 2018). Finally, we discuss how our results shed light on the historical association between certain psychoactive compounds and the experience of “dying”, on the possible neurobiological mechanisms underlying the robust and reproducible phenomenology of NDEs, on the possibility that NDEs are associated with the release of endogenous neuroprotective agents in the proximity of death, and finally on the possible therapeutic uses of pharmacologically inducing NDEs in the terminally ill.



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### 4.1.3 Materials and methods

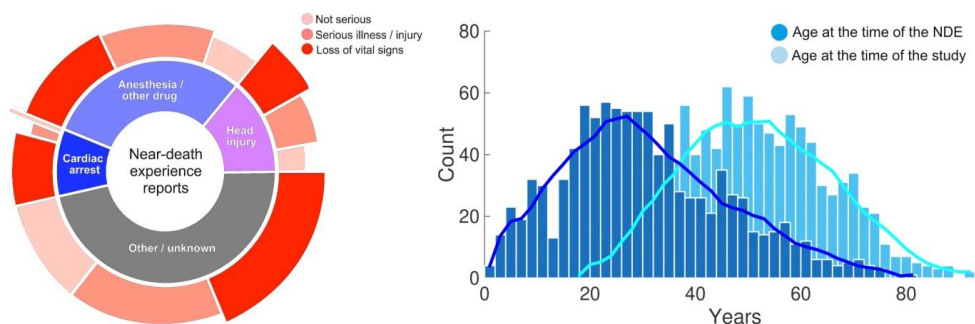
In the following, we describe the corpus of NDE narratives (“NDE corpus”), the demographics of the experiencers and the known circumstances at the time of the NDEs, as well as the corpus of free narratives of experiences with psychoactive compounds obtained from the Erowid Experience Vaults (“Erowid corpus”). We present an overview of the NLP tools applied to the corpora, especially of latent semantic analysis (LSA) (Landauer, Laham, & Derr, 2004), the core method to quantitatively compare the similarity of the reported experiences.

#### 4.1.3.1 NDE corpus

NDE experiencers were recruited via the Division of Perceptual Studies (University of Virginia Health System, USA) and the GIGAConsciousness (Coma Science Group, University of Liège and University Hospital of Liège, Belgium). Completion of the anonymous questionnaire was voluntary. The NDE corpus consisted of 625 retrospective narratives of NDEs, comprising a total of 623.926 words. All experiences scored 7 or higher on the NDE Scale ( $15.2 \pm 7$ ), except for 182 accounts which were collected before the development of such scale (Greyson, 1983). In those cases, the narratives contained enough detail to suggest they would have scored 7 or higher if the experiencers had completed the scale. Many narratives included additional information concerning participant demographics, nature of the circumstances surrounding loss of consciousness during the experience, severity of physical trauma/closeness to death, and self-assessment of the emotional valence of the experience (using a 3-point Likert scale ranging from -1 pleasant, 0 neutral, to +1 unpleasant). The age of the participants (68% females) at the time of the experience was  $31 \pm 15$  years (7 missing values), and the age at the time of the study was  $52 \pm 13$  years (2 missing values). Loss of consciousness at time of the NDE was attributed to head injury in 13% of the cases, to

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anesthesia/drug use in 30% of the cases, and to cardiac arrest in 10% of the cases (228 missing values). Severity of physical trauma/closeness to death was rated retrospectively by the experiencers as “not serious” in 27% of the cases, as “serious” in 37% of the cases and as involving loss of vital signs in 35% of the cases (209 missing values). The NDEs were rated as “pleasant” in 82% of cases, as “neutral” in 8% of cases and as “unpleasant” in 9% of cases (279 missing values). The NDE corpus metadata can be visualized in **Figure 7**.



**Figure 7** – Characterization of the NDE corpus metadata. Left: hierarchical pie chart showing the proportion of NDEs related to loss of consciousness due to head injury, anesthesia/drug use, cardiac arrest, and unknown causes. Each segment of the pie chart is further subdivided according to the severity of the physical trauma/closeness to death, divided into three categories: not serious, serious illness or injury, and loss of vital signs. The width of these outer segments is proportional to the average NDE Scale score (Greyson, 1983) of the experiences. Right: Histograms of the age of the experiencers at the time of the NDE, and at the time their accounts were retrospectively recollected.

### 4.1.3.2 Erowid corpus

Reports of psychoactive substance use were downloaded from the Erowid Experience Vaults (<https://erowid.org/experiences/>). The webpage

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www.erowid.org is defined as a “member-supported organization providing access to reliable, non-judgmental information about psychoactive plants, chemicals, and related issues”. Among other resources, it contains a large number (> 20,000) of curated freely expressed reports associated with the use of different psychoactive substances.

As described in a previous publication (Sanz et al., 2018), we curated the Erowid corpus by performing the following steps: (1) discarded reports that resulted from the combination of different substances; (2) discarding duplicate reports appearing under more than one category; (3) classified the reports in the most specific way unless such specificity dramatically reduced the number of reports associated with each individual substance; (4) distinguished the reports associated with plant and fungi and their isolated psychoactive compounds; (5) only included substances with more than ten reports. This resulted in 165 substances that were manually classified into the following classes: serotonergic psychedelics, dissociative psychedelics, entactogens, deliriants, depressants/sedatives, stimulants, antipsychotics/antidepressants, oneirogens (i.e., which produce dream-like states of consciousness) and others. Some substances were also given a secondary category due to the complex nature of their effects.

Following previous work, drug categories were determined using a hybrid criterion based on pharmacological action and the subjective effects induced by the substances. Serotonergic psychedelics (5-HT<sub>2A</sub> agonists) were grouped based on their mechanism of action (Nichols, 2016). The category of dissociative psychedelics comprised primarily NMDA antagonists such as the arylcyclohexylamines ketamine and PCP, but also included substances with other mechanisms of action (i.e., *Amanita muscaria* mushrooms) (Wallach & Brandt, 2018). Deliriants were in most cases Solanaceae plants rich in tropane alkaloids (El-Dabbas & Evans, 1982). Entactogen drugs were categorized by their subjective effects that produce specific social and emotional effects such as empathy, sociability enhancement, anxiety

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suppression and disinhibition (Nichols, 1986). Stimulants included dopaminergic drugs such as cocaine, amphetamines and modafinil, as well as others of different pharmacological profile; analogously, depressants/sedatives were defined by their effects on the central nervous system, and included substances such as benzodiazepines as well as natural and synthetic opioid analgesics (Perrine, 1996). Prescription antidepressants and antipsychotics were grouped together into one category. Only two plants in the Erowid corpus are consumed primarily for their oneirogen effect (*Calea zacatechichi* and *Silene undulata*) (Toro & Thomas, 2007). Certain substances had a large number of subjective reports, but their relatively unique mechanism of action did not justify the creation of a new category; such substances were classified as “other” (e.g., *Salvia divinorum*).

#### 4.1.3.3 Corpora preprocessing

The preprocessing of the NDE and Erowid corpora was performed using the Natural Language Toolkit (NLTK, <http://www.nltk.org/>) in Python 3.4.6. We applied the following steps: (1) separation into individual words after discarding all punctuation marks (word repetitions allowed); (2) word lemmatization using NLTK (i.e. conversion to the root from which the word is inflicted); (3) conversion to lowercase; (4) discarding words containing less than three characters (after lemmatization) (Sanz et al., 2018). Since texts from the Erowid corpus are likely to be influenced by the nature of the substance being reported, we manually compiled a list of words including substance names, different slang variations (e.g., “weed”, “coke”), and words relating to the possible routes of administration (e.g., “smoke”, “snort”, “inject”). These were removed from both the NDE and Erowid corpora. The rationale behind this “censoring” of the corpora was to retain words describing the experiences elicited by the substances, but not the drugs themselves nor contextual factors such as the route of administration.

#### 4.1.3.4 Latent semantic analysis

We employed an index of semantic similarity between narratives as a proxy of the similarity of the associated altered states of consciousness (Landauer et al., 2004). The main assumption behind our method is that if two subjects are asked to describe certain experiences, and both narratives mention the same core concepts with similar frequencies, then it is likely that both narratives reflect similar subjective experiences. Previous work has established the adequacy of LSA to classify the reported subjective effects of different psychoactive substances (Bedi et al., 2014; Coyle, Presti, & Baggott, 2012), and to compare drug-induced altered states of consciousness vs. non-ordinary experiences of a different nature (Bedi et al., 2014; Sanz et al., 2018).

As a first approximation, we define a matrix  $A$  with  $T$  rows (number of terms appearing in the corpus) and  $D$  columns (number of documents, in this case each document corresponds to all the reports of a substance in the Erowid corpus, or to all the narratives in the NDE corpus). This term-document matrix contains in its  $i, j$  entry the number of times the  $i$ -th term is mentioned in the  $j$ -th document. Then, it is possible to compute the similarity between documents  $j_1$  and  $j_2$  as the linear correlation between their corresponding columns in the matrix  $A$  (i.e., the documents are considered similar if the usage of terms is correlated between documents). It must be noted that the similarity is measured in terms of word co-occurrences, and not in terms of the frequency of single words. For instance, the word “fear” could appear frequently in a report of a frightful experience, but also in a report emphasizing absence of fear. However, the different co-occurrence frequencies of “fear” with other words will increase the semantic distance of the reports. A problem with this approach is only counting term occurrences, instead of computing their frequency weighted by how many times the term occurs within a given document vs. across the whole corpus. Thus, we applied the frequency-inverse document frequency (tf-idf) transform, as implemented in scikit-learn

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([www.scikit-learn.org](http://www.scikit-learn.org)). The entries of the matrix  $A$  are determined as the product of the term frequency and the inverse document frequency. The term frequency is defined as the number of times the term appears in each document. The inverse document frequency is defined as the logarithmically scaled inverse fraction of the documents containing the term. To eliminate very frequent/rare terms from the corpus, only those appearing in more/less than 5%/95% of the documents were retained. Intuitively, the tf-idf transform gives a higher weight to terms that are more specific to a given document, decreasing the weight based on the number of documents in the corpus that contain such term.

Another difficulty with the first approximation described above is that, for a large vocabulary of terms, the occurrence frequencies are sparse, i.e. most entries in the matrix  $A$  are zero and the linear correlation values of the columns are likely to be very low. By grouping words that appear in similar contexts as concepts, the number of independent variables used to span the semantic space is reduced. For this purpose, we applied LSA, a NLP tool based on the hypothesis that words with similar meaning appear with similar frequency in texts (Landauer et al., 2004). To apply LSA, the term-document matrix obtained using the tf-idf transform was first decomposed into the product of three matrices using Singular Value Decomposition (SDV) (Huang & Narendra, 1975),  $A = U \times \Sigma \times W$ . In this decomposition  $U$  and  $V$  are real unitary matrices and  $\Sigma$  is a diagonal matrix of singular values ordered by size. To reduce the dimensionality of the semantic space, only the first  $k$  singular values of  $\Sigma$  were retained, yielding the truncated matrix  $\Sigma_k$ . From this matrix, the rank-reduced term-document matrix is computed as  $A^* = Uk \times \Sigma_k \times Wk$ .

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#### 4.1.3.5 Principal component analysis and automated component labeling

We applied principal component analysis (PCA) to reduce the term-document matrix into a smaller number of components capturing topics that recurrently appear in the corpora (using an algorithm based on SVD as implemented in MATLAB 2014). We considered only the topics represented by the first five components, in terms of explained variance in the tf-idf rank-reduced term document matrix. Each component was associated with one coefficient per term in the vocabulary. These coefficients were used to represent the topics in word cloud format using the website <https://wordart.com/>.

To avoid the arbitrary naming of the components, for each of them we selected the 20 terms with the largest coefficients, and queried a large space for the words with the highest semantic proximity. For this purpose we used the Datamuse API (<https://www.datamuse.com/>), a word-finding engine based on word2vec (Minarro-Giménez, Marín-Alonso, & Samwald, 2014), an embedding method using neural networks to map words into a vector space with the constraint that words appearing in similar contexts are also close in the vector space embedding.

## 4.1.4 Results

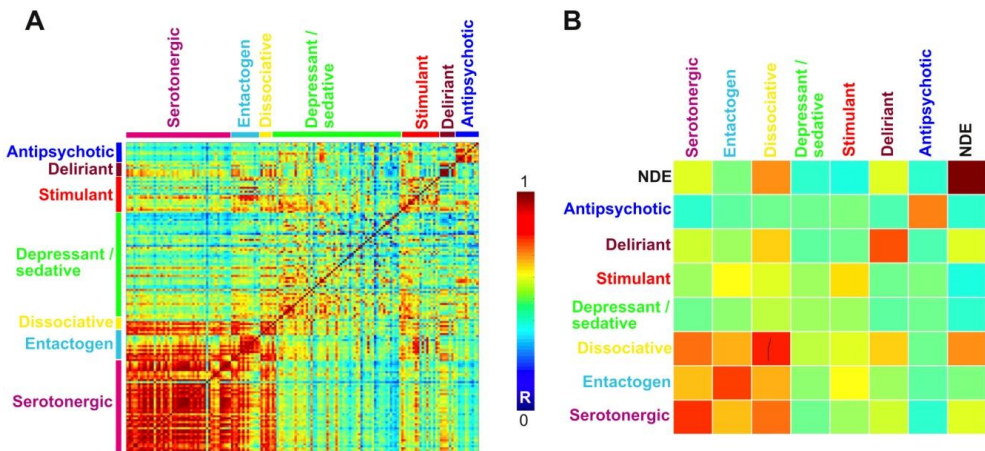
### 4.1.4.1 Similarity between NDE and drug-induced experiences

We performed a SVD of the term-document matrix, grouping as single documents all NDE narratives and all reports associated with the 165 substances in the Erowid corpus. We retained the first 20 singular values; this choice was based on the number of drug categories included in the corpus, as well as on previous research showing adequate results using the same dataset (Sanz et al., 2018). The robustness of the results against the choice of this parameter was evaluated and is presented in a latter section.

We obtained the correlation matrix derived from computing all pairwise correlations between the columns of the rank-reduced term-document matrix  $A^*$  (**Figure 8A**). The narratives of substances within the same category tended to display a higher semantic similarity when compared to those of other categories; this was especially clear for antipsychotics and deliriants. Stimulants and sedatives presented a smaller degree of within-group semantic similarity. Reports associated with the use of serotonergic and dissociative psychedelics and entactogens presented the highest within-group semantic similarity when considered together, but their differentiation was difficult. **Figure 8B** presents the average semantic similarity values for each substance category, and also includes the semantic similarity with NDE reports. It is evident upon direct visual inspection that NDE reports show the highest degree of semantic similarity with narratives of dissociative drug experiences.



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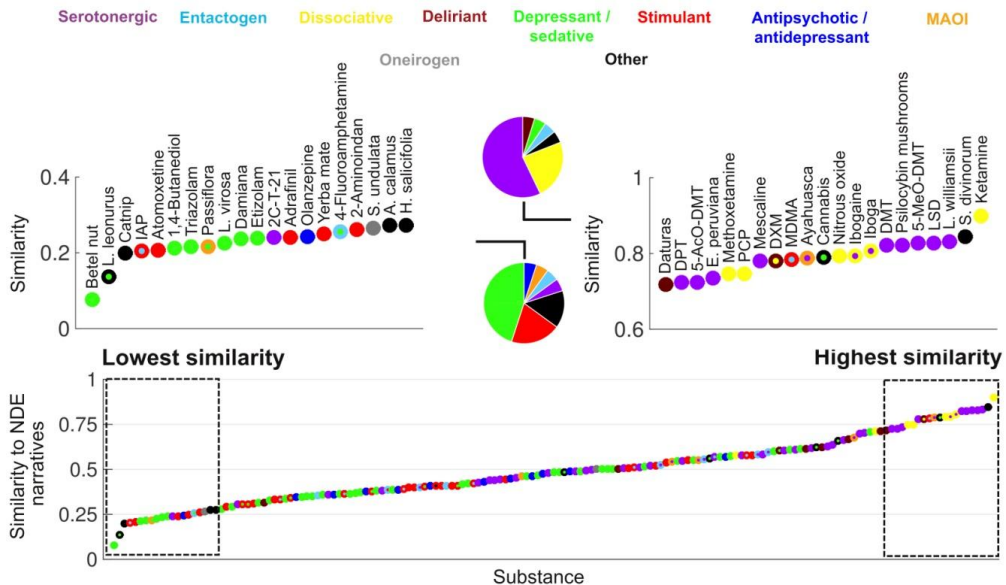
**Figure 8** – A. Pairwise document semantic similarity matrix obtained after applying LSA to the term-document matrix and retaining the 20 largest singular values. B. Matrix containing the average similarity values between all documents in each substance class, including the similarity with NDE narratives.

We then computed the semantic similarity between NDE narratives and those associated with each single substance. **Figure 9** presents a ranking of the substances in terms of such similarity. Each circle represents a drug that is color-coded based on its primary (center) and secondary (border) category. The rectangles in the left/right of the figure zoom into the 20 substances whose reports present the lowest/highest semantic similarity to NDE narratives. The pie charts indicate the proportion of each drug category in the top/bottom ranked substances. While the most represented category among the top 20 substances was that of serotonergic psychedelics, the dissociative psychedelic ketamine presented the highest similarity to NDE reports, followed by *S. divinorum*, and a series of naturally occurring (*L. williamsii*, 5-MeO-DMT, *Psilocybe* spp., DMT, iboga, ibogaine, ayahuasca, mescaline and *E. peruviana*), semi-synthetic (LSD) and synthetic (5-AcO-DMT, DPT) serotonergic psychedelics. Other dissociatives that ranked among the top 20 substances were nitrous oxide, PCP and methoxetamine.

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The only deliriant was the plant of the *Datura* genus. Conversely, the 20 substances with the lowest similarity to NDE narratives only included one serotonergic psychedelic (2C-T-21), and neither deliriant nor dissociative psychedelic. Most of the substances were either sedatives or stimulants.

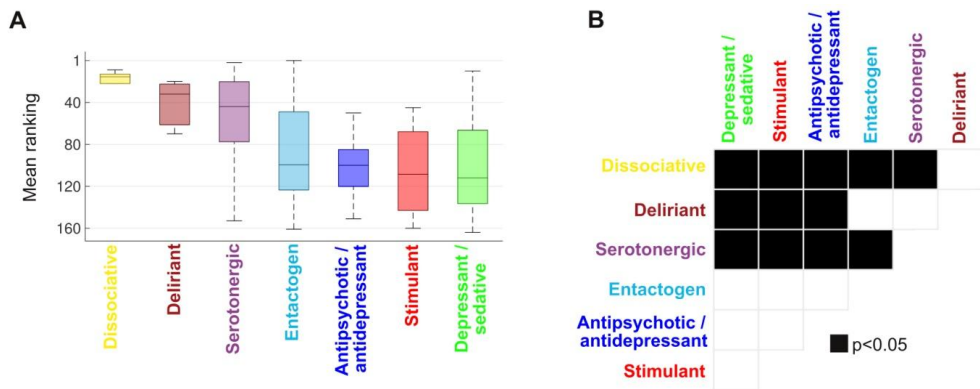
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**Figure 9** – Ranking of psychoactive substances in the Erowid corpus in terms of the similarity of their reported subjective effects to NDE narratives. The rectangles on the left/right zoom into the top 20 lowest/highest ranking substances. The pie charts indicate the proportion of each primary category within both rectangles. Substances are represented with circles that are color-coded based on their category (the color of the center / border corresponds to the primary/secondary category).

The boxplots in **Figure 10A** show the average ranking (in terms of semantic similarity to NDE narratives) for each substance category. Dissociatives ranked first, followed by deliriant and serotonergic psychedelics. Pairwise Wilcoxon signed-rank tests showed that the mean ranking of dissociative substances was higher than that of all other categories except deliriant. All hallucinogens (e.g., dissociatives, deliriant and serotonergic psychedelics) presented a higher average ranking than sedatives, stimulants and antipsychotics/antidepressants.

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**Figure 10** – A. Average substance ranking per category (in terms of the similarity of the reported effects to NDE narratives). Boxplots indicate median  $\pm$  25<sup>th</sup> and 75<sup>th</sup> percentiles. Lower numbers represent higher semantic similarity (i.e., the highest possible rank is 1, corresponding to ketamine). B. Pairwise Wilcoxon signed-rank tests for the difference in the semantic similarity to NDE narratives for each pair of drug categories. Black squares indicate a significant difference ( $p < 0.05$ ) for the pair of drug categories in the corresponding row and column.

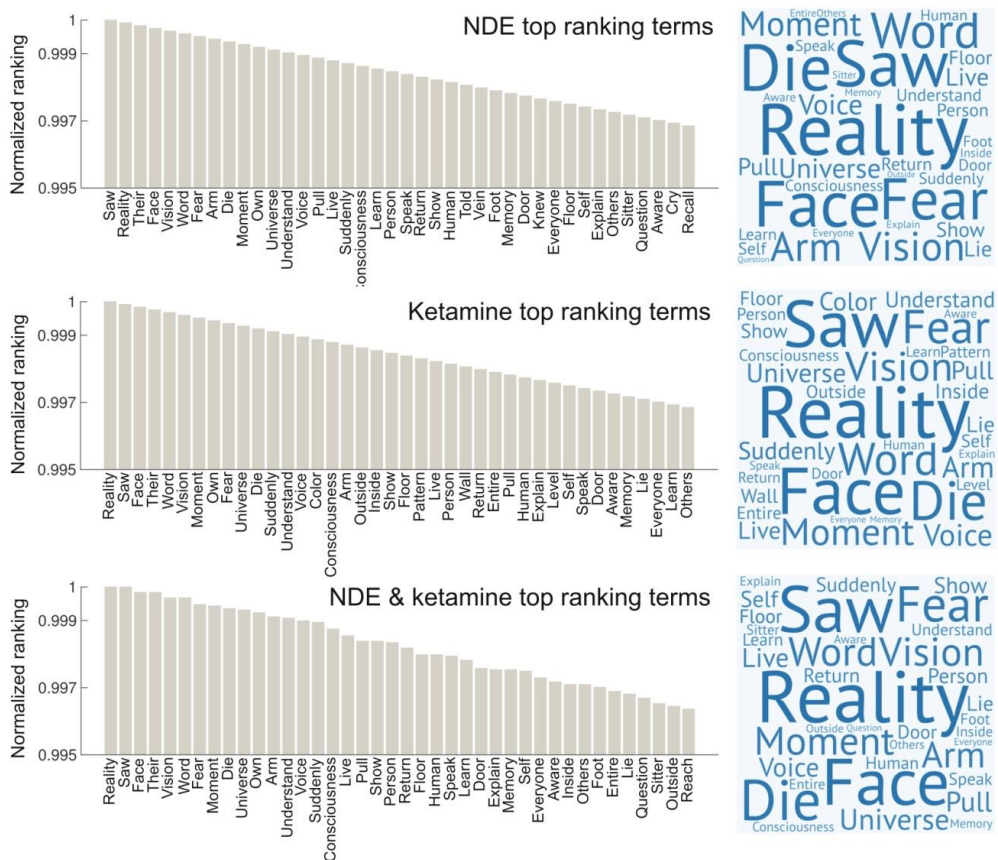
#### 4.1.4.2 Lexical and semantic similarities between NDE and drug-induced experiences

We then investigated the lexical and semantic features that related to the similarity between NDEs and reports of drug-induced experiences. We first ranked the terms based on their frequency of occurrence (obtained after applying the tf-idf transform) both in NDE and ketamine reports. We also computed the average ranking between both sets of reports, to identify those terms having a high prevalence in ketamine and NDE reports. Results are shown in **Figure 11**. The most common terms in both sets of narratives relate to perception (“face”, “vision”, “saw”), emotion (“fear”), consciousness and cognition (“reality”, “moment”, “universe”, “understand”, “consciousness”, “memory”, “explain”, “learn”), the self

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and others (“own”, “arm”, “self”, “person”, “human”, “everyone”, “others”) and setting (“door”, “floor”, “inside”, “outside”).

The comparison of the most frequent terms in both sets of experiences suggests shared phenomenological features associated with an altered state of perception of the self and the environment, and a departure from the everyday contents of conscious mentation. The application of PCA allowed us to classify these terms into recurrent topics appearing throughout both corpora.



**Figure 11** – Lexical similarity between NDE and ketamine reports. The upper panel presents the 40 most frequent terms in the NDE narratives, together with a word cloud representation (word size was weighted by the normalized ranking). The middle panel

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presents the same information for narratives of ketamine-induced experiences, while in the bottom panel terms are ordered based on the average frequency across both sets of narratives.

**Figure 12A** shows word clouds representing the first five principal components, which cumulatively described more than 60% of the variance in the data. The terms were weighted by the absolute value of their coefficients in the linear combination required to span each component. The names of the components were obtained by selecting words with the lowest semantic distance to the 20 most relevant terms in each component (using a trained word2vec model available in the Datamuse API, <https://www.datamuse.com/>). The first five principal components were the following:

1st: “Look/self”, included many of the shared terms between NDE and ketamine experiences (**Figure 12**), relating to perception, consciousness, and setting.

2nd: “Tone/negative”, placed a greater emphasis on negative bodily sensations (i.e., “body load”).

3rd: “Make/stuff”, included terms related to the preparation of natural materials with the purpose of extracting and isolating their psychoactive compounds.

4rd: “Take/dependency”, included terms clearly related to drug abuse, addiction and associated circumstances.

5th: “Disease/religion”, included terms related to diseases and their medical treatment, as well as others related to ceremonies, rituals and “spiritual” healing.

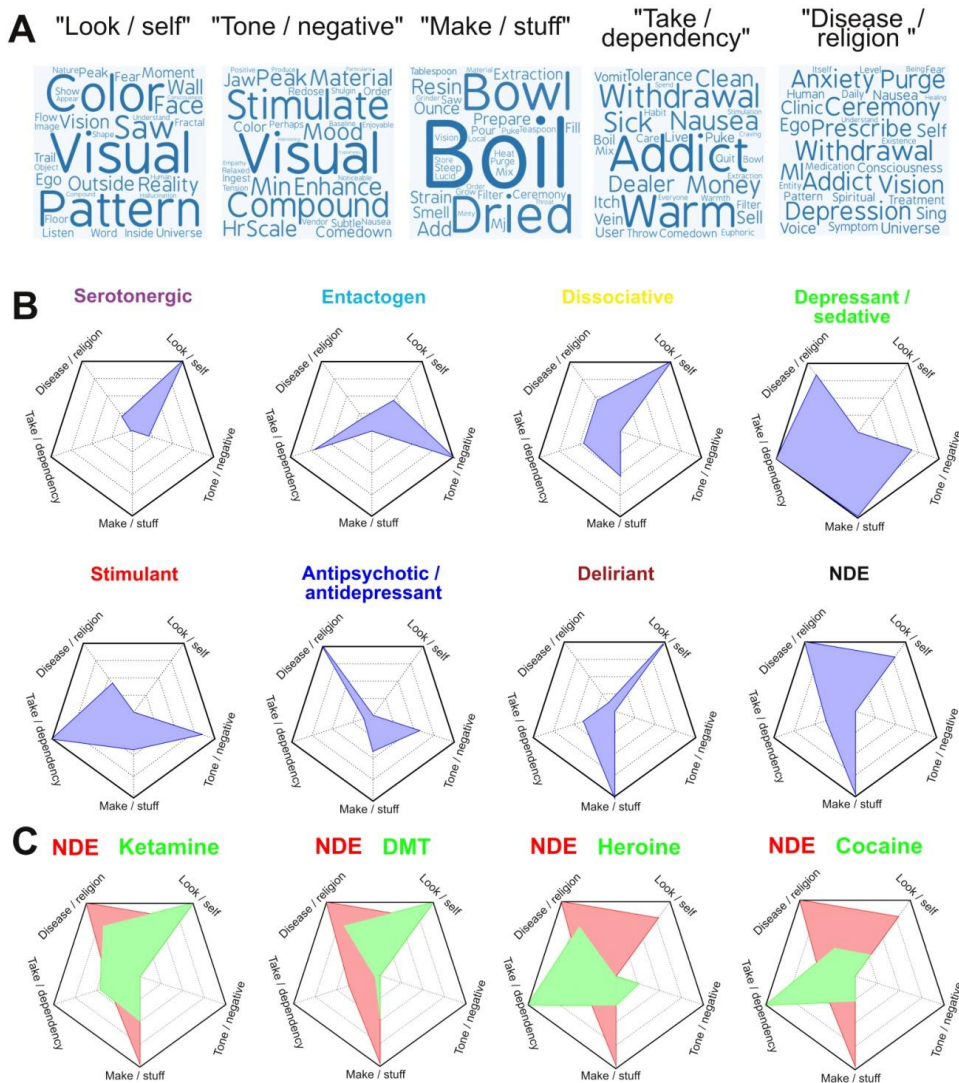
In **Figure 12B** we show the projection of each category of drugs into the five principal components, as well as the projection of the NDE narratives. The radar plots present “fingerprints” consistent with the known subjective and

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physiological effects of the drugs. For instance, serotonergic psychedelics projected almost exclusively into the “look/self” component, stimulants projected into the “take/dependency”/“tone/negative” components, antipsychotics into the “disease/religion”, and deliriants had the largest projections into the “look/self” and “make/stuff” components. NDE narratives projected into three different components: “look/self”, “disease/religion” and “make/stuff”.

To visualize the relationship between the semantic similarity of NDEs and the narratives associated with specific psychoactive substances, we superimposed the radar plots in **Figure 12C**. This comparison was done for the projections of NDEs vs. ketamine, DMT, cocaine and heroin reports. For the first two substances, the similarity with the NDE semantic “fingerprint” is apparent upon direct inspection, while for the other two substances obvious differences are manifest, mainly involving their projections into the “take/dependency” component.

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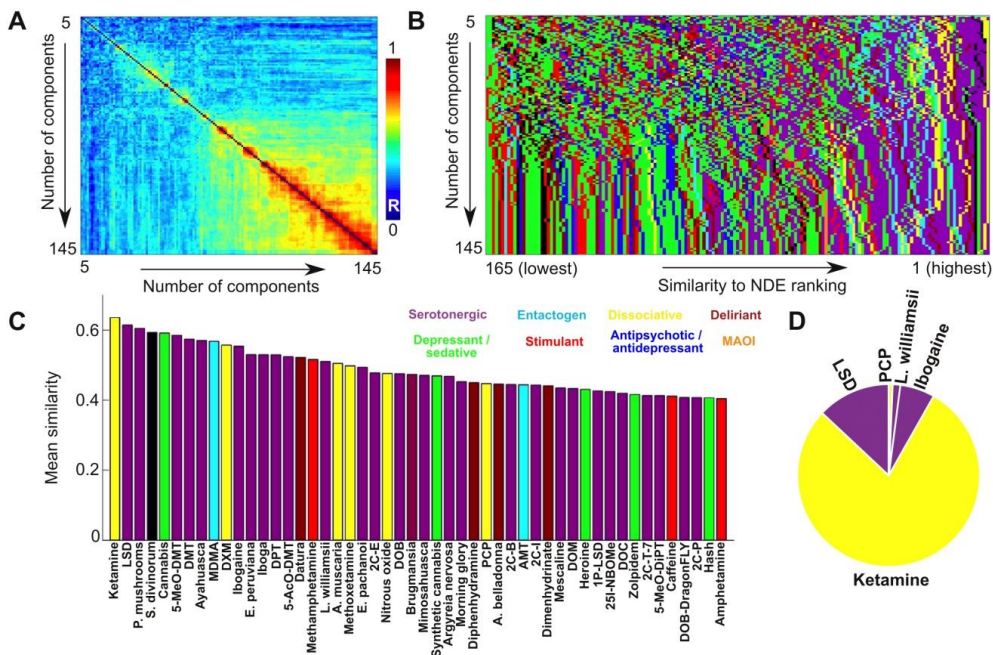
**Figure 12** – A. Five first principal components, ordered by decreasing explained variance. B. Radar plots showing the projections of the narratives (per substance category and NDEs) into each of the five principal components. C. Radar plots showing the comparison between the projections of NDE narratives into the five principal components and those of ketamine, DMT, heroin and cocaine narratives.



#### 4.1.4.3 Robustness vs. number of singular values retained

The SVDs performed in the previous sections retained the 20 largest singular values. In **Figure 13A** we show the correlation coefficient matrix for pairs of vectors that contain the rankings of the 165 psychoactive substances obtained using a number of singular values ranging from 5 to 145. We observe that modest to high correlations appeared near the diagonal of the matrix, indicating that small changes in the number of retained singular values did not dramatically alter the ranking of the substances. The correlations became more stable as the number of singular values was increased. We also note that two ranking vectors computed using a very different number of singular values (e.g., 20 vs. 100) compare poorly. In **Figure 13B** we investigate the robustness of substance category ranking vs. number of retained singular values. We observe that consistent results emerged for the highest ranked substances. In other words, while changing the number of singular values influenced the ranking of substances whose reports did not present a high semantic similarity to NDE narratives, those substances with a high semantic similarity to NDE narratives remained relatively stable. When computing the mean similarity across all choices of the number of retained singular values (**Figure 13C**), ketamine emerged again as the substance whose reports presented the highest semantic similarity to those of NDE, followed by a series of substances whose ordering is similar to that of **Figure 9**. From retaining 5–145 singular values, ketamine ranked first in most instances, followed by LSD, ibogaine, L. williamsii and PCP (**Figure 13D**).

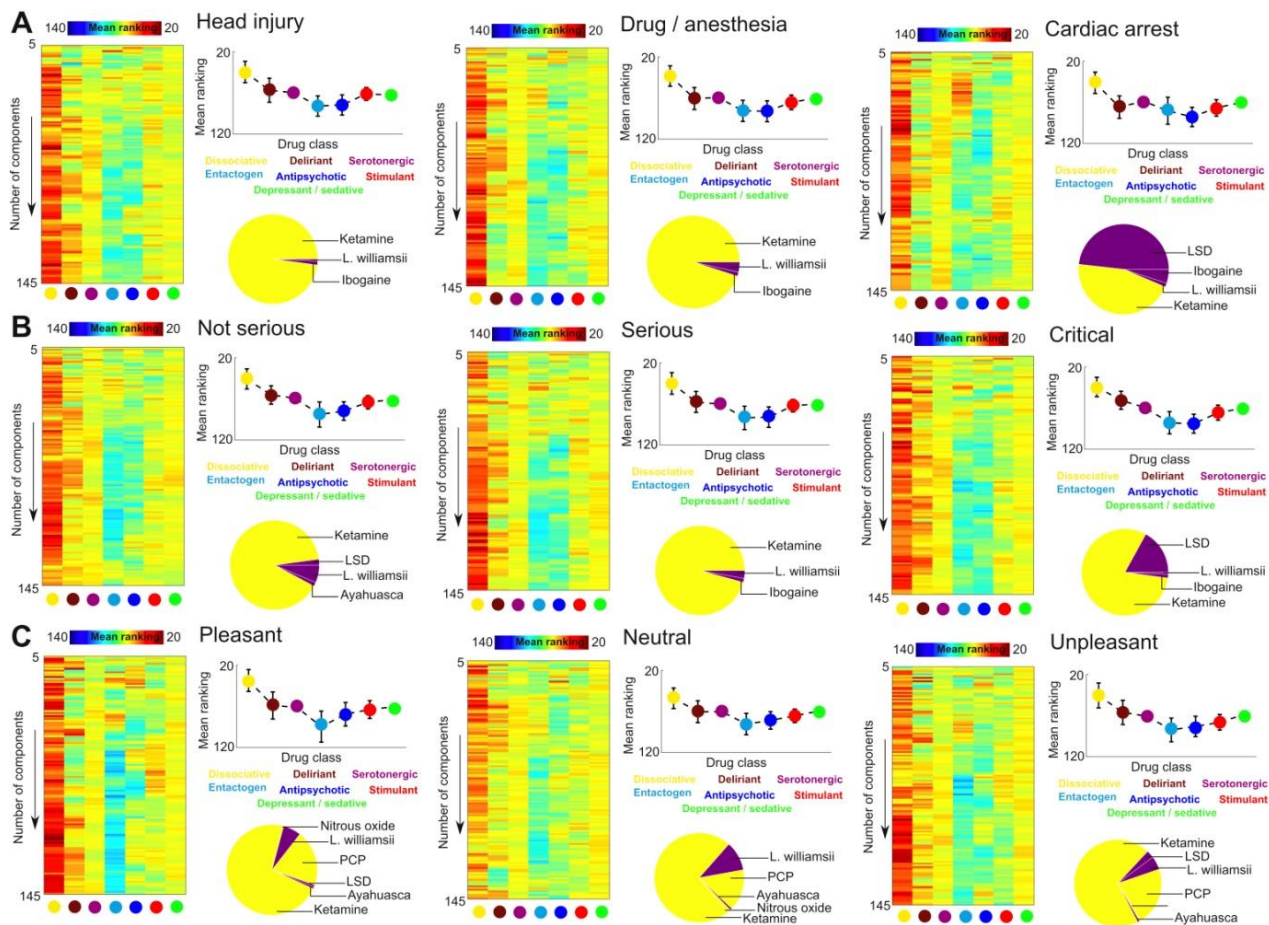
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**Figure 13** – Robustness vs. the number of singular values. A. Correlation matrix between the vectors that contain the rankings of the 165 substances (in terms of the similarity of their associated reports to those of NDE narratives), when computed using different numbers of retained singular values (from 5 to 145 singular values). B. Semantic similarity to NDE narratives as a function of the number of retained singular values, color-coded by the category of the drug in each ranking position. Substances with lower rankings were not stable against changes of this parameter, while the top ranked substances remained relatively stable. C. Substances ranked by their mean semantic similarity to NDE narratives (computed across all choices of the number of retained singular values, from 5 to 145). D. Pie chart showing the proportion of instances in which a substance ranked first (among all choices of the number of retained singular values).

#### 4.1.4.4 Relationship between semantic similarity and NDE metadata

We understand as “NDE metadata” all the information that is not contained in the NDE narratives themselves, but informs on the surrounding circumstances and demographics. In **Figure 14A**, we show the mean rating (in terms of NDE narrative semantic similarity) for each drug category, when comparing to NDEs associated with loss of consciousness due to head injury, anesthesia/drug use, and cardiac arrest. The mean ranking vs. drug category remained stable across conditions, and resembled that of **Figure 10A**. A similar result is shown in **Figure 14B** (proximity to death) and **Figure 14C** (emotional valence of the experience). As shown in the pie charts, ketamine emerged in almost all cases as the drug whose reports presented the highest semantic similarity to NDE narratives. The only exception was the comparison with NDEs associated with loss of consciousness induced by cardiac arrest, for which LSD ranked comparably to ketamine. Statistical analyses (one-way ANOVA) did not detect a significant effect of the NDE metadata on the drug ranking.



**Figure 14** – Similarity between narratives associated with substance use and NDEs of different cause, proximity to death and emotional valence. A. Semantic similarity between drug category and NDEs associated to loss of consciousness due to head injury, anesthetic agents/other drugs, and cardiac arrest. The rows of the matrices indicate the number of singular values retained in the SVD decomposition for LSA, and the columns indicate the drug category (color-coded as in **Figures 9 and 10**). The sub-panels include the average ranking per substance category, as well as pie charts showing the proportion of times that the reports of a given substance presented the highest similarity to those of NDE narratives. B. Same information as in panel A, but for NDEs separated by the proximity to death (not serious, serious and loss of vital signs). C. Same information as in panels A and B, but for NDEs separated by the emotional valence attributed by the experiencers (pleasant, neutral, unpleasant).

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#### 4.1.4.5 Replication of results with additional censored terms

To evaluate whether our main results depended on the presence of the contextual information in the “make/stuff” and “take/ dependency” components, we repeated the analysis after censoring the top 500 most relevant terms of each component. After applying LSA (retaining the highest 20 singular values), the top ten drugs in terms of the semantic similarity of their written reports to those of NDEs were the following: ketamine, ayahuasca, S. divinorum, L. williamsii, 5-MeO-DMT, LSD, Cannabis, Psilocybin mushrooms, iboga, nitrous oxide. Conversely, the ten least similar were: betel nut, atomoxetine, IAP, triazolam, yohimbe, passion flower, 2C-T-21, etizolam, olanzapine, 2C-T-4.

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#### 4.1.5 Discussion

Even disregarding processes at the sub-cellular scale and characterizing the  $\approx 10^{11}$  neurons as “on/off” binary units, the number of potential physical states of the brain is astonishing. Such complexity is required to support the highly differentiated nature of consciousness (Tononi, 2012; Tononi & Edelman, 1998). Given the diversity in the potential contents of human experience, it is remarkable that those contents can be organized into qualitatively different global states of consciousness. Even more remarkable is that analogies can be made between a finite set of “altered states”, whose underlying neurophysiological correlates are seemingly unrelated. Especially interesting are the comparisons between pharmacological and physiological or spontaneously occurring altered states of consciousness, since such comparisons could inform the development of neurochemical models for the latter (Luke, 2008; Strassman, 2001).

We addressed the long-standing analogy between the experience of dying and the acute effects of certain psychoactive drugs. Links between dying, death, a potential existence of afterlife and certain hallucinogenic plants and fungi emerged independently across different societies, and are also ubiquitous in contemporary psychedelic culture. However, scarce empirical research has been conducted to clarify the nature of this relationship. Unlike other human experiences, dying is difficult to study under controlled laboratory conditions by means of repeated measurements, which is a necessary condition to demonstrate within- and between individual robustness, and to determine a core set of phenomenological features. Lacking a precise definition, the association between pharmacologically altered states of consciousness and “dying” could represent the cultural propagation of an originally arbitrary association (i.e., “meme”) (Dawkins, 2016).

The systematic study of reports of individuals who survived close brushes with death suggests an alternative hypothesis. NDEs present a common core of

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robust and reproducible phenomenological features with relatively minor variations in terms of cultural background (Belanti et al., 2008), even though certain features (e.g., life review and tunnel sensations) were shown to depend on religious beliefs (Kellehear, 1993), and the robustness of NDEs does not necessarily imply a consistent temporal ordering of the defining phenomenological features (Martial, Cassol, Antonopoulos, et al., 2017) – although previous works have revealed certain consistencies across cultural backgrounds (Athappilly, Greyson, & Stevenson, 2006) and in terms of temporal ordering (Lange et al., 2004).

This body of empirical evidence supports that near-death is by itself an altered state of consciousness that can be investigated using quantitative psychometric scales (Greyson, 1983). Two studies followed this approach and compared experiences induced by ketamine (Corazza & Schifano, 2010) and DMT (Timmermann et al., 2018) to NDE phenomenology, the latter having the merit of assessing DMT phenomenology under controlled experimental conditions including a placebo. These studies support a significant overlap between both altered states of consciousness, yet a comparison including a wider range of substances is needed to systematically evaluate how such overlap depends on the pharmacological mechanism of action of different drugs, as well as on the neurophysiological changes elicited by them. The use of free narratives of drug-induced experiences presents many limitations (see below for a discussion), but nevertheless allows a comparison that is massive both in terms of the investigated drugs and the number of associated reports.

The comparison between NDEs and drug-induced experiences associated with an ample range of mechanisms of action offers the possibility of indirectly evaluating neurochemical models of NDEs. Strassman developed a parsimonious model for NDEs suggesting a relationship with DMT, a serotonergic psychedelic whose presence is demonstrated in human cerebrospinal fluid (Barker, McIlhenny, & Strassman, 2012; Strassman, 2001). The author further hypothesized that DMT

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production primarily occurs in the pineal gland, given its unique location outside the blood-brain barrier and high concentrations of both serotonin and methyltransferase enzymes (Barker, Borjigin, Lomnicka, & Strassman, 2013), which are required for in vivo conversion of tryptamine to DMT. However, postmortem attempts to isolate DMT from pineal glands were unsuccessful (Strassman, 2001). Regardless of these considerations, both our analysis and the recent work by Timmermann and colleagues (2018) established that DMT-induced experiences present a substantial overlap with NDEs, with especially strong associations between DMT-induced near-death type experiences and mystical-type experiences, and the feelings of “ego-dissolution”, “unitive experience” and “oceanic feeling”. This study also established associations between NDE-like DMT experiences and certain personality traits (this association with personality traits is also known in other types of NDE-like); in agreement with the observation that both NDEs and psychedelic experiences are highly dependent on contextual factors (Greyson, 1993; Nichols, 2016). Our study established the similarity of both experiences by means of free narratives. The application of dimensionality reduction techniques (PCA) revealed discrete components with similar ratings between DMT experiences and NDEs, especially in components related to alterations in conscious perception of the environment and the self (“look/self”) and therapeutic, mystical and spiritual aspects of the experience (“disease/religion”). These results are consistent with the use of psychometric scales by Timmermann *et al.* (2018). We must note, however, that it has not been established that the numerical ratings extracted from free narratives are equivalent to those obtained using psychometric scales— even though preliminary analyses have been conducted for the NDE Scale (Lange et al., 2015). Importantly, our analysis revealed that such commonalities were not specific to DMT experiences, but common to other serotonergic psychedelics as well. Among the top 20 substances eliciting experiences most similar to NDEs, more than 50% of them were serotonergic psychedelics, including *L. williamsii*, LSD, 5-MeO-DMT and mushrooms of the *Psilocybe* genus, all of them ranking higher than DMT.



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A possible biological role for the release of endogenous DMT at times of stress is related to its neuroprotective effects, in particular, the prevention of cell death due to hypoxia and oxidative stress mediated via  $\sigma_1$  receptor agonism (Frecka, Szabo, Winkelman, Luna, & McKenna, 2013; Szabo et al., 2016). These effects remain to be demonstrated in humans; furthermore, Nichols has argued that endogenous DMT production could not reach concentrations sufficiently high to elicit any noticeable changes in subjective experience (Nichols, 2018). Our analysis revealed that ketamine, a synthetic arylcyclohexamine dissociative anesthetic, was associated with narratives most similar to those of NDEs, regardless of the circumstances surrounding the NDEs, the actual proximity to death and the emotional valence assigned by the experiencers. Ketamine acts by antagonism at the PCP site of glutamate NMDA receptors. Such antagonism has been shown to prevent cell death due to the excitotoxicity caused by hypoxia (Church, Zeman, & Lodge, 1988; Rothman & Olney, 1986). Many studies and clinical trials have established that ketamine shows neuroprotective and neuroregenerative effects in humans, even when administered after onset of cerebral insult, improving the clinical outcomes related to stroke, brain injury and status epilepticus (Church et al., 1988; Fujikawa, 1995). This led Grinspoon and Bakalar (Grinspoon & Bakalar, 1997) and subsequently Jansen (Jansen, 1989; Jansen, 1997a, 1997b) to suggest that an endogenous ketamine-like compound is released at times of stress and is responsible for the remarkable similarities between ketamine-induced experiences and NDEs. Candidate endogenous agents (“endopsychosins”) (Jansen, 1990) have been found in animal tissues, but are likely complex neuropeptides and their molecular structure remains to be determined (DiMaggio, Contreras, Quirion, & O’Donohue, 1986). Other substances suggested as endogenous neuroprotective NMDA antagonists are N-acetylaspartyl-glutamate, kynurenic acid and agmatine (Luke, 2008). The role of glutamate in NDEs is further supported by shared similarity with certain types of epilepsy associated with massive glutamate release (Laureys, Gosseries, & Tononi, 2016; Morse et al., 1989).

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The hypothesis of DMT and endogenous NMDA antagonists as the sole causes of NDEs has received extensive criticism, both in terms of the associated phenomenology and neurobiological plausibility. NDEs can occur in situations in which the threat is only apparent or even absent (e.g., NDE-like phenomenology during hypnagogic or meditative states) and brain cells are not under direct stress (Fenwick, 1997); however, Jansen did not rule out the possibility of an anticipatory NMDA receptor blockade, stating that “there is no reason to suspect that the NDE mechanism would never be activated spontaneously” (Jansen, 1997a, 1997b) – indeed, our analyses ranked ketamine-experiences as the most similar to NDEs regardless of the proximity of death (**Figure 14B**). Furthermore, OBEs are one of the most salient features of ketamine experiences (Wilkins, Girard, & Cheyne, 2011), which Grinspoon and Bakalar described as “... becoming a disembodied mind or soul, dying and going to another world. Childhood events may also be re-lived. The loss of contact with ordinary reality and the sense of participation in another reality are more pronounced and less easily resisted than is usually the case with LSD. The dissociative experiences often seem so genuine that users are not sure that they have not actually left their bodies” (Grinspoon & Bakalar, 1997). It has been shown that OBEs are frequent in NDEs associated with cardiac arrest (French, 2005), as well as in other kinds of NDEs (Charland-Verville et al., 2014), supporting a link to NMDA receptor blockade via an endogenous ketaminelike compound.

Differences in NDE and ketamine-induced phenomenology have been noted, especially between the generally blissful nature of NDEs and the potential occurrence of ketamine “bad trips” (Fenwick, 1997). This objection can be countered by noting that the blissful nature of NDEs may have been overestimated (Greyson & Bush, 1992), that contextual factors (“set and setting”) play an important role in the emotional valence of NDEs and ketamine experiences (Greyson, 1993; Grinspoon & Bakalar, 1997) and finally noting that the subjective effects elicited by an endogenous NMDA antagonist do not need to exactly match those of ketamine (unless that antagonist is ketamine itself). In support of the

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ketamine model, it has been argued that subjects who experienced both NDEs and ketamine report a remarkable similarity between both experiences (Jansen, 1997a, 1997b). Criticism to the ketamine model is based on the observation that not all individuals in the proximity of death actually report an NDE (Sleutjes et al., 2014); however, a similar percentage of the population is unable to recall their ketamine experiences (Jansen, 1997a, 1997b). Conversely, neurochemical models based on other serotonergic psychedelics received criticism due to the divergence between typical psychedelic imagery and the hallucinatory content present during NDEs. Nevertheless, DMT is known to produce more immersive experiences with intense imagery that can include tunnel-like visions and encounters with seemingly autonomous “entities” (Strassman, 2001; Strassman, Qualls, Uhlenhuth, & Kellner, 1994). The strong association between ketamine and OBEs is shared with NDEs, but is less manifest in the case of serotonergic psychedelics, including DMT (Wilkins et al., 2011).

Our analysis included reports from a large number of substances and thus allowed the exploration of drugs whose phenomenology is not commonly associated with that of NDEs. While on average the phenomenology of substances classified as dissociatives was the most similar to NDEs (with significantly higher similarity than that of serotonergic psychedelics), reports associated with the use of deliriant also presented a high semantic similarity to NDE narratives. These comprise plants of the *Datura* and *Brugmansia* genera, which are rich in alkaloids of anticholinergic effect known to induce complex and interactive hallucinations, a general state of confusion and anterograde amnesia (El-Dabbas & Evans, 1982; Iglesias-Lepine, Mariñosa, Ferrer-Da Pena, & Epelde, 2012). Drug users frequently lack the insight to identify the imagery as hallucinatory. Analogously, individuals who report NDE are also known to believe in the reality (i.e., corresponding to appropriate real external stimuli) of the experienced events (Schwaninger et al., 2002) due to the experienced clear sensorium. However, since the tropane

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alkaloids present in these plants are toxic, it is possible that the semantic similarity was driven by descriptions of real life-threatening situations.

Similar considerations may apply to *Salvia divinorum*, a very potent hallucinogen that is considered safe, but is known to be occasionally smoked by users who believe are consuming cannabis (Vohra, Seefeld, Cantrell, & Clark, 2011). This plant contains salvinorin A, a highly selective and potent agonist of the  $\kappa$  opioid receptor (Chavkin et al., 2004) capable of producing intense visual, auditory, somatic and vestibular distortions (Addy, Garcia-Romeu, Metzger, & Wade, 2015; Sumnall, Measham, Brandt, & Cole, 2011). The intensity of the experience elicited by this drug relative to cannabis may represent a shock to unsuspecting users, who could retrospectively report the belief of being close to death. Nevertheless, it is interesting to note that opiate antagonists (which block the subjective effects of salvinorin A) (Sheffler & Roth, 2003) such as naloxone can increase survival time in fatal or near-fatal circumstances (Holaday & Faden, 1978), leading to the hypothesis that certain endorphins (mainly betaendorphin, known to increase in concentration of bodily fluids of dogs moments before their death) (Sotelo, Perez, Cuevara, & Fernandez, 1995) can mediate NDE-like phenomenology (Carr & Prendergast, 1981). However, beta endorphins present high selectivity for  $\mu$  opioid receptors, whose activation, unlike  $\kappa$  receptors, is implicated in processes such as analgesia, sedation and euphoria, but not in the production of hallucinations (Loh, Tseng, Wei, & Li, 1976). Certain endorphins (e.g., dynorphin) bind preferentially to  $\kappa$  receptors (Chavkin, James, & Goldstein, 1982), but there are no experimental results that link them directly to NDEs. The endorphin model of NDEs also presents limitations stemming from the fact that agonism at opioid receptors can produce effects that do not resemble the phenomenological features of NDEs (Sivanesan, Gitlin, & Candiotti, 2017).

It is interesting to note that the PCA decomposition of the narratives yielded similar “fingerprints” for DMT, ketamine and NDEs (**Figure 12**), in contrast

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to other two control substances (cocaine and heroin). This was mainly due to the fact that these two hallucinogens presented a relative high projection into the “look/self” and “disease/religion” components. The first likely reflects the departure from ordinary conscious perception characteristic of these drugs and NDEs (also manifest in the lexical analysis presented in **Figure 11**). With respect to the “disease/religion” component, both ketamine and DMT (as part of the Amazonian concoction ayahuasca) have been explored for therapeutic uses, especially for the treatment of major depression (e.g., Kyzar et al., 2017). The presence of words related to spiritual and religious contexts suggests that the potential therapeutic benefits of these substances appear intertwined with ceremonial use in the Erowid corpus (Dakwar et al., 2018; Niciu et al., 2018). This suggestion is supported by the evidence that dissociative NDEs at the time of trauma may provide some therapeutic benefit in reducing the risk of full-blown post-traumatic stress disorder (PTSD; Greyson, 2001). NDEs are known to produce long-lasting effects, some of which are deemed positive by the experiencers, such as changes in their personal understanding of life, self, and personal relations, modifications in their social customs as well as in their religious or spiritual beliefs and their interest in material possessions and social status (e.g., Bianco et al., 2017; Kellehear, 1990; Parnia et al., 2007). Increased psychological well-being and self-worth have been linked to NDEs (Noyes, 1980). It is interesting to note that psychedelics were shown to induce similar long-term effects (Forstmann & Sagioglou, 2017; Gasser, Kirchner, & Passie, 2015; Griffiths et al., 2016; Grob et al., 2011). These commonalities lend support to Kenneth Ring’s early speculation on the “universality” of transcendental experiences: “The authenticity of a transcendental experience is revealed by its transformative effects (...). My reading of the evidence suggests that whether the trigger be a spontaneous mystical experience, a psychedelic episode, or an NDE, once this core is activated, it begins to unfold and bring about transformation in much the same way, as if an archetype of transformation were engaged” (Ring, 1988). However, it must also be noted that

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both psychedelics and NDEs can be distressing experiences with negative sequelae. The changes in personal beliefs can be sudden and disorienting, and feelings of anger, depression and estrangement from family and friends have been reported (Duffy & Olson, 2007; Greyson, 1997). There have also been symptoms of PTSD associated with NDEs, even though avoidance symptoms are less prevalent, leading to the suggestion that the positive affect linked to NDE-dissociative episodes mitigate PTSD symptoms that frequently arise from other dissociative experiences (Greyson, 2001). Overall, it is clear that both NDEs and certain hallucinogenic drugs with similar phenomenology, such as ketamine and serotonergic psychedelics, can induce long-lasting effects on personality and well-being, but further research is needed to precisely determine the nature of these effects and their prevalence. Finally, NDE reports also presented a significant projection into the “make/stuff” component, likely representing contextual information and the description of activities not directly related to the NDEs. Nevertheless, the similarity with the reports of ketamine-induced experiences remained the highest even after censoring the 500 most relevant terms of the “make/stuff” and “take/dependency” components.

Neurochemical models of NDEs can be theoretically attractive; however, we must emphasize that the analyses conducted in the present work neither validate nor refute these models, since they are based on retrospective reports and no physical examinations of the subjects at the time of the reported NDEs were performed. Regardless of the validity of different neurochemical models of NDEs, a very interesting question was posed by R. Strassman: “if so, so what?” (Strassman, 1997). In other words: even if the validity of one of these models is confirmed, why is neuroprotection linked to substances such as ketamine-like compounds and/or DMT, which are also known to elicit an altered state of consciousness frequently characterized by feelings of bliss and transcendence? Why is neuroprotection by endogenous substances not associated with unconsciousness, or with feelings of distress and aversion? It has been shown that decreased fear of death can be a

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long-term consequence of NDEs (Greyson, 2007); thus, NDEs seemingly lack adaptive value. However, this conclusion relies on the assumption that decreased fear of death leads to less caution or increased risk-taking behavior. Also, it could be argued that elderly individuals are more likely to experience health problems leading to NDEs, and that feelings of aversion towards death could result in the prolonged competition for resources with individuals who have more potential to reproduce. Furthermore, NDE-dissociative episodes might mitigate PTSD symptoms linked to other dissociative experiences (Greyson, 2001) and NDE experiencers seem to endorse more anti-suicidal attitudes as compared to non-NDE experiencers who have come close to death (Greyson, 1993), thus adding support to the potential adaptive value of these experiences. In any case, drugs that mimic NDE phenomenology might also reduce death-related anxiety, suggesting a potential therapeutic use for the terminally ill. Evidence exists that certain drugs whose reported subjective effects present a high semantic similarity to NDE reports can alleviate end-of-life anxiety in patients with advanced stage cancer, i.e., psilocybin, LSD and ketamine (Griffiths et al., 2016; Grob et al., 2011; Kolp et al., 2007).

Given the nature of our analyses, our discussion is biased towards the discussion of neurochemical models of NDEs. However, unless direct empirical evidence is obtained, we can only affirm that the reported phenomenology of certain drugs is similar to that of NDEs, and that those drugs could be effective tools for the safe and temporary induction of NDE-like altered states of consciousness in controlled laboratory settings. It is nevertheless certain that these laboratory-induced NDEs may be a mere “reflection” of “authentic” NDEs. Like all models, those based on the effects of psychoactive drugs present limitations. For instance, certain effects of subanaesthetic doses of ketamine are not among the features that characterize NDEs, arguing against the reductionist explanation of NDEs as a consequence of NMDA receptor blockade (Adler et al., 1999; Dillon, Copeland, & Jansen, 2003). Other models have been proposed that are not directly

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related to endogenous psychoactive compounds, but to alterations in neural activity in certain brain areas, primarily in temporal lobe regions (Britton & Bootzin, 2004; Saavedra-Aguilar & Gomez-Jeria, 1989). Multifactorial explanations for NDE phenomenology have also been proposed. Mobs and Watt argued that each “classic” feature of this phenomenology can be explained via a different mechanism, e.g., awareness of being dead as a form of Cotard syndrome, OBEs as a failure to integrate multisensory information, the perception of a tunnel of light as a consequence of retinal ischemia, etc. (Mobbs & Watt, 2011). However, it has been pointed out by Greyson and colleagues that this article only accounted for those features that could be explained by the authors, while ignoring other features that are regarded as the most defining for NDEs (Greyson, Holden, & van Lommel, 2012). Furthermore, these alternative models must also be understood as speculative, given the lack of experiments performed at time of reported near death. Few experiments have investigated the neurophysiological changes associated with the ceasing of vital functions. Most strikingly, a surge of coherent high frequency (gamma, >25 Hz) oscillations preceding isoelectric activity has been demonstrated both in humans and animal models (Borjigin et al., 2013; Chawla et al., 2017). However, Greyson and colleagues provided a series of arguments against the interpretation of these short surges of “hyperactivity” as neural correlates of NDEs (Greyson, Kelly, & Dunseath, 2013). It is nevertheless important to note that serotonergic psychedelics such as LSD and psilocybin result in broadband reductions of brain oscillations (Carhart-Harris et al., 2016; Muthukumaraswamy et al., 2013), while ketamine enhances gamma oscillations in parietal and cingulate cortices and medial frontal theta oscillations, and decreases occipital, parietal and anterior cingulate alpha power (Lazarewicz et al., 2010; Muthukumaraswamy et al., 2015). While these results suggest commonalities (alpha power decreases) and divergences (gamma power increases) between the spectral changes elicited by ketamine and serotonergic psychedelics, muscle artifacts are known to heavily affect high frequency bands under the effects of the latter (Muthukumaraswamy et



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al., 2013), and increased gamma oscillations have been reported for ayahuasca and LSD (Muthukumaraswamy & Liley, 2018; Sattar et al., 2018; Schenberg et al., 2015). It is therefore difficult to compare the spectral changes elicited by serotonergic psychedelics and ketamine, and those recorded during the cease of vital functions.

Our study presents both advantages and limitations stemming from the use of a large number of retrospective narratives. In both cases, these narratives rely on the memory of the event. The time between the occurrence of the NDEs and participation in the study averages approximately two decades (Greyson, 2007). Reports of subjective effects from Erowid Experience Vaults are likely closer to the time of substance use, but present several limitations of their own. While substantial relevant data was available for the participants of the NDE study, demographical information is not commonly available for Erowid users. Reports could be contaminated by expectation effects, and most lack laboratory verification of the identity and dose of the consumed substances, which may be even unknown to the users reporting the experiences. Dose could bias the results if subjects consumed higher doses of ketamine compared to those of serotonergic psychedelics such as LSD and psilocybin, resulting in dissociation and feelings of disembodiment only for the latter. However, DMT is known to produce these effects at relatively low doses when smoked or administered intravenously (Strassman et al., 1994; Winstock, Kaar, & Borschmann, 2014), and ketamine reports still presented a higher semantic similarity to those of NDEs than the DMT reports. Another limitation is the relative cultural homogeneity of the population. However, currently no other sources of data exist that include a large number of reports for an equally large number of substances.

In conclusion, we have systematically compared the semantic similarity of reports associated with the use of psychoactive compounds and NDE narratives, and found evidence that ketamine (and to a lesser extent different serotonergic psychedelics and deliriant alkaloids) can produce an altered state of consciousness

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resembling near-death. With the available experimental data, it is neither possible to corroborate nor refute the hypothesis that the release of an endogenous ketamine-like neuroprotective agent underlies NDE phenomenology. However, our results do provide evidence that ketamine, as well as other psychoactive substances, result in a state phenomenologically similar to that of “dying” (understood as the content of NDE narratives). This could have important implications for the pharmacological induction of NDE-like states for scientific purposes, as well as for therapeutic uses in the terminally ill as means to alleviate death anxiety. We believe that the development of evidence-based treatments for such anxiety is a cornerstone of a more compassionate approach towards the universal experience of transitioning between life and death.

## 5 Conclusion and perspectives

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The present thesis revolves around three main axes: i) to contribute to a better characterization of the phenomenology of NDEs (**study 1** and **study 2**); ii) to investigate the type of autobiographical memory they could be associated to (**study 3** and **study 4**); and iii) to explore potential neurochemical models of NDEs (**study 5**).

Given the augmenting number of NDE testimonies and the impact of these experiences on peoples' lives (van Lommel et al., 2001), it appeared crucial to reach a better description of the phenomenon. The content of NDEs has been the focus of numerous studies at the very dawn of NDE research. Since then, the phenomenon came out of the taboo atmosphere, leading to an increasing amount of testimonies worldwide. This craze resulted in a growing body of descriptions that differed from the initial prototypical NDE (i.e., Moody's core experience; 1975) which undeniably called for new rigorous studies aiming at extracting the main NDE features.

In **study 1**, henceforth, we used a qualitative thematic analysis to detail the rich phenomenology of these experiences in a sample of cardiac arrest survivors. In order to provide new insights, “blind” experts in thematic analysis went through tens of written narratives. Experts were blinded to etiology and were naïve to the field of NDEs. Obviously, NDEs are regularly discussed in the lay literature and the experts may not have been strictly blinded, however, we wanted to enhance methodological rigor and reduce measurement biases by limiting any substantial influence of existing literature and preconceived notions on the processing of the narratives. For example, researchers' knowledge of existing quantitative scales (e.g., Greyson NDE scale; Greyson, 1983) could have had an incidence when extracting the main themes. In total, we extracted 11 themes: one “transversal” and ten “time-bounded” themes. The “altered time perception” emerged as the only transversal theme. This theme shapes the whole experience and cannot clearly be isolated from the other NDE characteristics. Unlike the ten other features, it does not correspond to a limited moment of the event. Additionally, analysis pointed out that it is generally addressed retrospectively by NDE experiencers, while they are engaged in reflections about the

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event. In contrast, “time-bounded” themes have more limited time duration and are generally described as clear isolated events. The identified time-bounded themes were the following: “light”, “return”, “meeting/encounter”, “hyperlucidity”, “description of scenes”, “darkness”, “OBE”, “awareness of death”, “life events” and “entrance in the NDE”.

The major benefit of this approach is that, contrary to closed questionnaires, it brings information about the combination of features and further provides a broader overview about the spontaneous description of such ineffable experiences. What particularly drew our attention is that the “feeling of peacefulness” and “joy” have not been identified as full-fledged themes. By highlighting this, we do not deny that a majority of NDEs is positively perceived (which makes them undeniably unique given their context of occurrence –i.e., the life-threatening situation—), but we rather emphasize that a heterogeneous range of emotions seem to be associated with them. As underlined by the text analysis, “light”, “hyperlucidity”, and “awareness of death” are generally linked to positive emotions such as well-being, happiness, serenity and amazement. On the contrary, “OBEs”, “meeting”, “darkness”, “life events”, “description of scenes” and “return” are related to conflicting emotions, ranging from well-being or amazement to confusion, unbearable sadness, fear or pain. Finally, “entering the NDE” and “altered time perception” are less frequently associated with emotional qualifiers. Given the existence of distressing feelings in detailed written accounts, it is unfortunate that negative emotions are overlooked by presently available tools designed to identify NDEs (e.g., Greyson, 1983; Ring, 1980).

These contrasting emotions and the non-identification of positive feelings as full-fledged themes stroked our curiosity and brought us to dig deeper into the phenomenon of distressing NDEs. Conclusions about these frightening events were inescapable: hard facts about them are scarcely available and recent data inexistent. Consequently, **study 2** was conceptualized in response to this lack of empirical evidence. Several interesting results came out from our analyses. First, distressing

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NDEs represented 14% of our NDE sample, while previous studies rather reported percentages ranging from 1% to 10% (e.g., Charland-Verville et al., 2014; Greyson & Bush, 1992). Second, we confirmed Greyson and Bush's (1992) classification consisting of inverse, void and hellish frightening NDEs, and we identified an equal number of inverse and hellish NDE narratives as well as one void experience. Third, distressing and classical NDEs only differed on the affective component of the Greyson NDE scale, suggesting that negative experiences include as much transcendental, paranormal and cognitive elements as classical ones. Interestingly, some distressing accounts began with feelings of peacefulness and could therefore be misinterpreted as predominantly positive on the unique basis of existing scales. Fourth, distressing NDE memories appeared to be as phenomenologically detailed as classical ones (i.e., similar memory clarity, amount of sensory, self-referential, emotional and contextual details). Finally, the prevalence of suicidal attempters was higher among distressing NDE experiencers.

Altogether, results of **studies 1** and **2** should draw our attention on three main points. First, the greater proportion of suicides in frightening experiences may support and reflect the strong implication of "top-down" processes in the emergence of the NDE phenomenon. In moments where sensory inputs are missing or degraded such as during altered states of consciousness, the content of conscious experiences is influenced by previous knowledge, beliefs, state of mind and expectations in order to mentally "fill in the gap" (Blackmore, 1996; Martial et al., 2018). Hence, the psychological context surrounding suicidal attempts could more easily lead to negatively toned experiences. Consistent with this view, studies have for example highlighted the culture-related incidence of some NDE features (e.g., tunnel vision; Belanti et al., 2008; Kellehear, 1993; Pasricha & Stevenson, 1986), suggesting that the religious and cultural backgrounds could also shape NDEs' content (Blackmore, 1993). Even though a core component to NDE may exist (e.g., OBEs, meeting with religious figures and the vision of a light seem to be described in different cultures), a cultural impact must therefore be considered when interpreting individual accounts. Further

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studies appear necessary to elucidate the influence of experiencers' state of mind, expectations, culture, religion and society on the content of the NDE phenomena.

The second point is that future efforts should also focus on developing and validating a new scale to measure NDEs in the future, in order to characterize them in the finest possible way. Currently, the only used scales are the Greyson NDE scale (Greyson, 1983) and the WCEI (Ring, 1980), both created in the eighties. A new scale built upon latest findings and based on robust statistical analyses are needed to identify NDEs, especially since current questionnaires only screen positive emotions and could not be sufficiently sensitive to detect their negative homologous.

The third and last point that we need to address is the overall amount of details provided in narratives and the vividness associated with NDE memories, either negative or positive. These observations are not unprecedented. Considerable research has focused on the phenomenology of these memories (e.g., Martial, Charland-Verville, Cassol, et al., 2017; Moore & Greyson, 2017), notably showing that they are more likely to display richer perceptual information and more contextual details (spatio-temporal information) compared to memories of imagined (e.g., fantasies or unfulfilled goals) or even real events (Thonnard et al., 2013). Thus, authors concluded that NDE memories could not be considered as typical imagined events (Thonnard et al., 2013). The "superiority" of real event memories in comparison to imagined ones in terms of phenomenological richness is in fact well established. For instance, Johnson and collaborators (1988) demonstrated that real events include larger amounts of contextual information like the time and the place where the event took place, perceptual details such as colors or sounds, and more emotional information. Several studies later corroborated this finding (e.g., Johnson, 2006; McGinnis & Roberts, 1996; Takahashi & Shimizu, 2007). What remains poorly understood, however, is why NDE memories are allegedly more vivid than other memories of real event recollections (Thonnard et al., 2013). In their experiment, Thonnard *et al.* (2013) compared NDE memories with an old and a recent real event

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memory, showing that NDE memories were phenomenologically richer, and ultimately concluded that they would be more detailed than real-life event memories. Yet, little is known about the type of other real event memories that were selected by experiencers in this study. Were these landmark or trivial episodes? In other words, are NDE memories really more detailed than any other kind of real event recollections? These findings led some authors to formulate different hypotheses about the nature of NDE memories: i) Martial and collaborators (2017) suggested that they could be considered as “SDMs”; and ii) Thonnard and coworkers (2013) that they could meet the definition of “flashbulb memories”. Consequently, we decided to test these assumptions by means of two distinct protocols (i.e., the former in **study 3** and the latter in **study 4**).

In **study 3**, we investigated the hypothetical self-defining value of NDE memories. To do so, NDE and NDE-like experiencers were contacted and asked to evoke their two main SDMs. First, results showed that 58% of the entire sample recalled the NDE as a SDM, respectively 63% of real NDE experiencers and 48% of NDE-like experiencers. This high percentage of NDE-like experiencers strongly suggests that the self-defining aspect of the NDE memory could be at least partly explained by its content, and not only by the life-threatening context surrounding the event. Second, we found a larger proportion of religious (i.e., at the time of the NDE) people among experiencers who recalled their NDE, compared to those who did not. Thereon, it is reasonable to hypothesize that some aspects of the phenomenon, such as the mystical and transcendental compounds (e.g., entering an unearthly world, meeting with deceased relatives/religious spirits), might be perceived as more meaningful for religious experiencers. Third, when only considering the subsample of experiencers who recalled the NDE, we found that NDE memories are rated as being more “central” to peoples’ identities and life stories compared to other recalled SDM, as measured by the CES (Berntsen & Rubin, 2006). In other words, they can be considered as turning points and cornerstones in experiencers’ lives. Finally, we also noted that half of the NDE memories did not include “meaning making”, yet this



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process would be essential to good mental and physical health, especially during hardships related to death and loss (Inder et al., 2008; Mackay & Bluck, 2010). Interestingly, many theories suggest that PTSD is in fact a disorder in autobiographical memory and that the incomplete processing of a traumatic event would largely contribute to the further development of PTSD symptoms. In this view, memories of traumatic events are poorly integrated in one's life and fragmented, unlike other autobiographical memories (Berntsen & Rubin, 2014). Thereupon, as stated earlier, we may hypothesize that atypical experiences of close brushes with death, like NDEs and distressing NDEs in particular, may become reference points that could potentially lead to deleterious outcomes such as PTSD symptoms if they are not adequately processed.

From a clinical perspective, **study 3** therefore raises awareness on the relevance of developing psychological interventions to foster the integration of NDEs into experiencers' life story and identity. On a similar note, effort should be made to launch the creation and dissemination of practice guideline recommendations about NDEs among medical healthcare professionals. This clinical framework could prevent a potential feeling of alienation among all kinds of experiencers by developing a non-judgmental and psychologically safe environment in which they feel free to share, to process and to integrate their experience. Besides, this could reduce caregivers' burden by offering tools and strategies to deal with NDE testimonies.

**Study 4** was developed concomitantly to address the second hypothesis: can recollections of NDEs meet the definition of flashbulb memories? This was done by comparing the NDE, a flashbulb and a control autobiographical memory dating from the same period. Results first showed that NDE verbal recollections comprised a greater amount of episodic information (i.e., event, perceptual and emotional details directly related to the main event) than control autobiographical and flashbulb memories, as well as more non-episodic (i.e., event details external to the main event) information than flashbulb memories. Second, flashbulb memories were

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associated to a lesser intensity of feelings upon recall and a lower personal importance, and are less frequently reactivated and less susceptible to be remembered from a first person perspective compared to NDE and control autobiographical memories. Lastly, NDE memories were considered more central than control autobiographical memories, which in turn are more central than flashbulb memories.

Altogether, results of **study 4** indicate that NDE memories distinguish themselves from flashbulb memories in many aspects. NDE recalls were particularly rich even though they were generally reported after decades, a factor that is known to reduce the detail and vividness of a memory (Talamini & Gorree, 2012). Although they contained more episodic details (as measured by the AI protocol; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002) and were considered more central (as measured by the CES; Berntsen & Rubin, 2006) than other autobiographical and flashbulb memories, they did not always differ from control autobiographical events regarding the amount of phenomenological details assessed by the MCQ subscores (Johnson et al., 1988). The analysis cannot allow us to clearly state that they are phenomenologically similar, however, the comparable scores observed for NDE and autobiographical memories may be explained by the fact that the latter were sometimes related to the NDE (e.g., memories of their hospitalization) and that some of them could also fit the definition of a SDM (i.e., some NDE experiencers recalled potential life-changing events such as their child's birth).

In the literature, vividness is often evoked as a central component for mentally reliving autobiographical memories (van Schie, Chiu, Rombouts, Heiser, & Elzinga, 2019). Previous studies have shown that, at the neural level, more vivid memories are associated to an increased activation of specific key regions (van Schie et al., 2019): the bilateral hippocampi, which are related to the quality of remembering an experience (e.g., Addis, McIntosh, Moscovitch, Crawley, & McAndrews, 2004; Burgess, Maguire, & O'Keefe, 2002), the bilateral activation of the

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amygdala, associated to emotionality (Cabeza & St Jacques, 2007; Geib, Stanley, Wing, Laurienti, & Cabeza, 2017) as well as the right anterior and posterior insula (Deen, Pitskel, & Pelphrey, 2011), involved in self-awareness (Pais-Vieira, Wing, & Cabeza, 2016). The anterior part of the insula is generally associated to the awareness of emotionality and saliency of subjective experience, and its posterior part to the awareness of body sensations (Craig, 2009, 2011; Simmons et al., 2013). This entire activation pattern is indicative of autonoetic consciousness; a sense of recursive and introspective mental time travel (e.g., Lehner & D'Argembeau, 2016). Additionally, van Schie and coworkers (2019) suggested that vivid memories were associated to enhanced mood during recall. Precisely, authors highlighted that vividness had a greater impact on affective and neural responses during positive memories compared to neutral ones. They suggested that emotional memories may assist pre-reflective self-awareness (i.e., a process allowing individuals to perceive themselves as the immediate actors of their experience, unextended in time; Gallagher, 2000), which in turn would support the feeling of re-experiencing the positive emotions related to the event. This enhanced emotionality would be beneficial when purposefully reflecting on the self (Dritschel, Beltsos, & McClintock, 2014). Even though this greater impact of vividness on the mood felt upon recall was shown for positive vs. neutral memories, a similar pattern could also be found for negative memories, such as distressing NDEs which also display high memory vividness and intensity of feelings while remembering. Further studies should determine the process and activation specific to more negative events.

In the light of the above, it is easier to conceive why NDE memories remain highly vivid and detailed despite the passage of years. Characteristics such as their high emotionality and their self-defining value (observed in a majority of cases) were demonstrated to be critical to memory vividness. Besides, despite the fact that they are central first-hand experiences and that they lead to different verbal recollections than those of flashbulb events, these two memories share key components such as emotionality at the time of the event, novelty (i.e., they are related to unprecedented

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events) or long-lasting memory traces. In sum, NDE memories could be regarded as a particular type of “SDMs with flashbulb-like features”.

On the contrary, what **study 3** and **4** cannot answer is how people keep such a deep trace of an event that typically occurred in the context of a life-threatening situation often involving a cardiac arrest (generally associated to amnesia of the event; Parnia, Spearpoint, & Fenwick, 2007), and potentially under the influence of psychoactive medications, which may alter memory as well (Curran, 2000). It is, however, interesting to mention that memory enhancement for emotional memories could be linked to the release of adrenal stress hormones such as adrenaline/epinephrine and cortisol (LaLumiere, McGaugh, & McIntyre, 2017). In their study, Cahill and Alkire (2003) showed that if adrenal stress hormones are administered to participants after an encoding phase, memory consolidation will be facilitated and recall will consequently be enhanced. Besides, epinephrine is utilized during cardiopulmonary resuscitation. Extrapolating from these studies, one could assume that encoding and consolidation of the NDE memory after a cardiac arrest could be related to the release of specific neurotransmitters such as epinephrine.

Nonetheless, we should keep in mind that the exact moment these experiences take place remains unknown, and their specific neural correlates have not been identified yet. As a matter of fact, classical authentic NDEs are impossible to predict, which makes simultaneous high-resolution brain monitoring impractical. To sidestep this hurdle, several models have been suggested to approach the NDE phenomenon in a safe and reversible manner. Among those, some neurotransmitters and drugs were evoked because of their resemblance with the NDE, notably DMT and ketamine (e.g., Jansen, 1997b; Timmermann et al., 2018). In order to reach a more accurate idea of an adequate drug model for NDEs, we explored the semantic similarity between 625 NDE narratives and ≈15 000 reports linked to the use of 165 psychoactive substances in **study 5**. Results indicated that the NMDA receptor antagonist ketamine corresponds to the reports that are the most similar to those

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associated with NDEs. *Salvia divinorum* ranks second and is followed by a series of serotonergic psychedelics, notably the endogenous serotonin 2A receptor agonist DMT. Similarity between accounts was unsurprisingly influenced by concepts associated to consciousness of the self and the environment (i.e., words relating to perceptions, senses and/or the setting such as “color”, “visual”, “inside” or “universe”), but also by therapeutic, ceremonial and religious aspects. Overall, our analysis indicates that ketamine could indeed be used as a safe and reversible pharmacological model to study the phenomenology of NDEs. Moreover, results suggest that endogenous NMDA antagonists with neuroprotective properties could be released during close brushes with death.

Along with this pharmacological approach, other physiological models to NDEs have also been tested such as vasovagal syncope, which may trigger episodes identified as NDEs-like and therefore regrouping several NDE features (i.e., Greyson NDE scale scores  $\geq 7$ ; Charland-Verville et al., *in preparation*). Moreover, some specific NDE features such as OBEs can be reproduced under IVR (i.e., IVR may be used to visually replace the person's real body by a life-size virtual body seen from the first person perspective, therefore, when the viewpoint is lifted up, it may result in an OBE; Cassol et al., *in preparation*) or relived by NDE experiencers themselves through hypnosis techniques (see the methods reported elsewhere by Faymonville et al., 2003; Martial, Mensen, et al., 2019). These models offer the opportunity to reproduce one or several NDE feature(s) in a controlled laboratory setting while recording the brain's activity and connectivity by means of high-density EEG or functional magnetic resonance imaging. Correlating these measures could ultimately bring new insights about the neural correlates of such experiences. In addition to these promising pharmacological and physiological models, future studies should also consider reproducing and expanding results of end-of-life electrical surges (ELES) identified in human studies (Chawla et al., 2017, 2009). Chawla and coworkers (2017) have demonstrated that these ELES are common among patients who suffer cardiac arrest. Interestingly, authors reported that for the subset of ELES that were witnessed by one

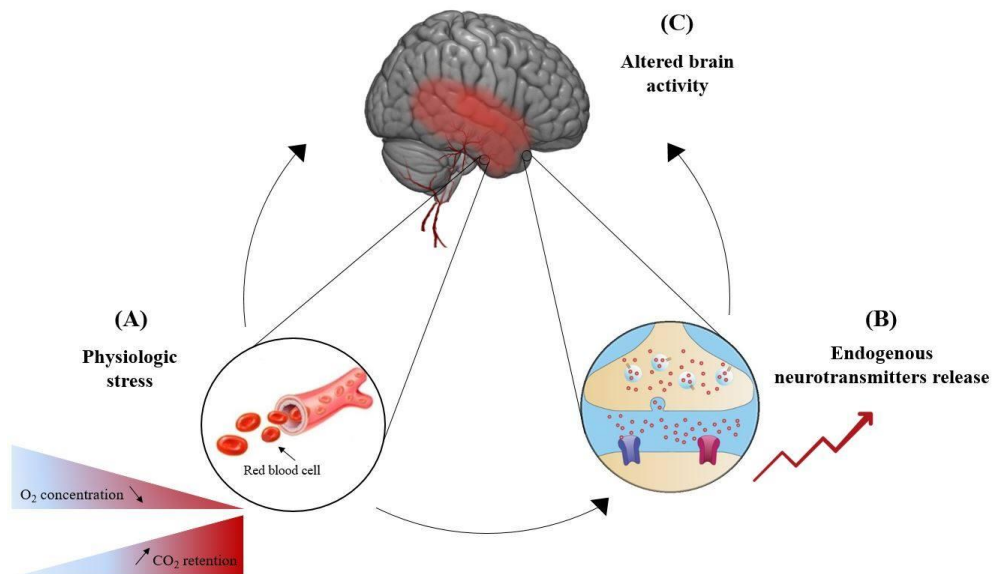
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of the investigators, patients seemed unconscious and were motionless even though the neuromonitoring was compatible with an increased level of consciousness. In a previous study (Chawla et al., 2009), investigators suggested that the mechanism of ELES might be due to neuronal networks that have retained their membrane potential when facing a loss of blood flow. In other words, when oxygen levels are depleted, neurons may depolarize in a cascade, thereby provoking high frequency EEG signals, which could be interpreted as “a last gasp survival mechanism” (Chawla et al., 2017, p. 391). Interestingly, other phenomena might provide some mechanistic insights to explain the NDE phenomenology during altered states of consciousness. Even though this phenomenon is still poorly documented, a hypothesis similar to the “last gasp survival mechanism” was evoked to explain episodes of paradoxical lucidity in patients suffering from Alzheimer’s disease just before they die, even though they present an irreversible degeneration of the cerebral cortex and the hippocampus, resulting in severe memory loss (Mashour et al., 2019). Authors have suggested that this paradoxical lucidity may be the consequence of synaptic modifications, complex adjustments in signaling cascades, neuronal interactions and compensation for functional inhibition due to neurotoxic proteins (Mashour et al., 2019; Palop, Chin, & Mucke, 2006). Overall, however, more data are needed to establish or refute a link with NDEs, and to determine if EEG patterns of ELES are sufficient in strength and duration to account for these experiences.

Given that we are currently unable to determine when NDEs occur exactly, the debate about their underlying processes is still open, and the phenomenon therefore still challenges some theories and postulates about consciousness. This is evidenced, for example, by the fact that several authors have discussed that these experiences are a strong argument in favor of non-local consciousness hypotheses which assume that consciousness does not always coincide with the functioning of the brain (Parnia, 2007; van Lommel, 2013).

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Even though neurosciences have not yet produced a definitive theory supported by empirical data to account for the entire NDE phenomenon, it clearly appears that research has made considerable progress in that direction (French, 2009; Martial, Cassol, Laureys, & Gosseries, *under review*). Indeed, we have provided several examples that could support a neurophysiological possibility of paradoxically rich subjective experiences during altered states of consciousness. Overall, efforts should consequently be made to develop and test a model that would include a combination of the neurobiological factors potentially involved in the emergence of NDE features as illustrated, albeit very schematically, in **Figure 15**. Lake (2017), for example, recently built a multifactorial NDE model according to which highly integrated dynamic networks (i.e., “connectomes”) would be triggered by psychological and/or physiological factors such as fear, traumas or drug intakes.



**Figure 15 – Illustration of neurophysiological mechanisms possibly involved in the emergence of NDEs (Martial et al., *under review*).** This illustration includes potential causal agents of NDEs: (A) physiologic stress comprising altered levels of blood gases, such as transient anoxia and hypercarbia (e.g., Klemenc-Ketis et al., 2010; Lempert et al., 1994) and,

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probably occurring secondarily, B) natural or drug-induced release of endogenous neurotransmitters including N-methyl-D-aspartate (NMDA) antagonists and endorphins (e.g., Carr & Prendergast, 1981; Jansen, 1991). Both factors may lead to (C) dysfunctions of specific brain regions such as the temporal lobe (Blanke, 2005) and the anterior insular cortex (e.g., Picard & Kurth, 2014).

Given their specific phenomenology and their potentially distinct neurophysiologic markers, NDEs could be regarded as a state of consciousness on its own. More specifically, these experiences could be regarded as episodes of internal awareness (e.g., mental imagery, inner speech, or mind-wandering) while being disconnected from the environment (Martial et al., *under review*; Sanders, Tononi, Laureys, & Sleight, 2012). Thus, they would correspond to a state of “disconnected consciousness” with a specific content/phenomenology and their own biological fingerprint, thereby being distinct from other episodes of disconnected consciousness such as dreams.

Before concluding this work, it is important to address limitations that might hinder the generalizability of some of our results. First, the scarcity of NDEs did influence the recruitment of our participants and sometimes led to relatively small sample sizes that might have impacted some of our analyses. We did not perform a priori sample size estimation and power analyses; however, we aimed at testing as many participants as possible, in an exploratory fashion. We therefore acknowledge that some of our analyses might be underpowered, thereby hindering the detection of potentially interesting effects. Moreover, our research work being exploratory and observational, we sometimes examined large amounts of variables and consequently set stringent statistical thresholds. In the future, larger hypothesis-driven studies targeting more specific variables of interest are required to confirm some of the results and trends yielded by our work.

Second, because of these limited sample sizes and experimental constraints, there was a participant overlap between some studies (see **Table 21**). **Study 1** and



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**study 2** are retrospective analyses of data collected through calls in the media, following which participants completed questionnaires and provided a written narrative of their experience. Two NDE experiencers were included in both studies. However, the overlap does not imply a reanalysis of the same data since **study 1** explored their written narratives and **study 2** their answers to the Greyson NDE scale and the MCQ. **Study 3** and **study 4** were conducted later and included some NDE experiencers that had already been involved in the two previous researches. Nevertheless, we have no reason to expect that the inclusion of these participants in previous studies might have influenced results of **study 3** which was a distinct task related to the centrality of their NDE as well as the self-defining dimensions of its memory. Issues related to the overlap of samples could however arise with regard to **study 4** which assessed the quantity of episodic and non-episodic details comprised in three types of autobiographical memories, including the NDE. Indeed, it could be objected that their previous recall may have impacted the number of details provided in participants' verbal recollections, since rehearsal is known to strengthen memory trace and consolidation (e.g., Himmer, Schönauer, Heib, Schabus, & Gais, 2019). However, we believe that this previous inclusion may only have a limited impact on our results given that NDE memories are frequently reactivated and recalled anyhow (i.e., see results of the MCQ question 16). Additionally, a majority of NDE experiencers described the NDE memory as a SDM, whose particularity is to be frequently brought into memory and talked about.

Overall, considering the relative scarcity of NDEs and the challenge to recruit such experiencers, it is reasonable to say that the studies included in the present thesis exhibit relatively limited overlap.

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**Table 21. NDE experiencers overlap between the different studies.**

	<b>Study 1</b> Thematic analysis	<b>Study 2</b> Distressing NDE accounts	<b>Study 3</b> NDE vs. SDMs	<b>Study 4</b> NDE vs. flashbulbs	<b>Study 5</b> Neurochemical models			
<b>Study 1</b> Thematic analysis	n=34							
<b>Study 2</b> Distressing NDE accounts	n=2					n=123		
<b>Study 3</b> NDE vs. SDMs	n=2					n=14*	n=71	
<b>Study 4</b> NDE vs. flashbulbs	n=2					n=7*	n=13	n=25
<b>Study 5</b> Neurochemical models	n=0					n=625		

\*the overlap only relates to NDE experiencers who had lived positive NDEs as determined by the MCQ.

To conclude, NDEs are subjective events with a neurophysiological basis that have aroused curiosity and led to myths and legends for centuries (Thonnard et al., 2008). If their underlying neural correlates and states of consciousness have not been precisely identified yet, we now know that they may lead to vivid SDMs likely to have a significant impact on people's lives. Consequently, we believe that an even better comprehension of the phenomenon would lead to a more appropriate recognition of what NDE experiencers have been through and counteract a possible feeling of alienation.

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