Designing for Self-transcendent Experiences in Virtual Reality

by

Alexandra Jean Kitson

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Declaration of Committee

Name: **Alexandra Jean Kitson**

Degree: **Doctor of Philosophy**

Thesis title: **Designing for Self-transcendent Experiences in Virtual Reality**

Committee:

Chair: Kate Hennessy
Associate Professor, Interactive Arts and Technology

Bernhard E. Riecke
Supervisor
Professor, Interactive Arts and Technology

Alissa Antle
Committee Member
Professor, Interactive Arts and Technology

Andrea Gaggioli
Committee Member
Professor, Psychology, Universita Cattolica del Sacro Cuore

Steven Barnes
Examiner
Associate Professor, Psychology, University of British Columbia

Giuseppe Riva
External Examiner
Professor
Department of Psychology
Universita Cattolica del Sacro Cuore

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Abstract

This thesis contributes to Psychology and Human-Computer Interaction (HCI) research with a focus on the design of immersive experiences that support self-transcendence. Self-transcendence is defined as a decrease in a sense of self and a increase in unity with the world. It can change what individuals know and value, their perspective on the world and life, evolving them as a grown person. Consequently, self-transcendence is gaining attention in Psychology, Philosophy, and Neuroscience. But, we are still far from understanding the complex phenomenological and neurocognitive aspects of self-transcendence, as well as its implications for individual growth and psychological well-being. In reviewing the methods for studying self-transcendence, we found differing conceptual models determine different ways for understanding and studying self-transcendence.

Understanding self-transcendence is made especially challenging because of its ineffable qualities and extraordinary conditions in which it takes place. For that reason, researchers have began to look at technological solutions for both eliciting self-transcendence to better study it under controlled and replicable conditions as well as giving people greater access to the experience. We reviewed immersive, interactive technologies that aim to support positive experiences such as self-transcendence and extracted a set of design considerations that were prevalent across experiences.

We then explored two different focuses of self-transcendence: awe and lucid dreaming. First, we took an existing VR experience designed specifically to support the self-transcendent experience of awe and looked at how the mindset and physical setting surrounding that VR experience might better support the experience of and accommodation of awe. Second, we delved deep into lucid dreaming to better understand the aspects that could help inform the design of an immersive experience that supports self-transcendence. We put those design ideas into practice by developing a neurofeedback system that aims to support lucid dreaming practices in an immersive experience.

Through these review papers and design explorations, we contribute to the understanding of how one might design and evaluate immersive technological experiences that support varieties of self-transcendence. We hope to inspire more work in this area that holds promise in better understanding human nature and living our best lives.

Keywords: virtual reality; immersion; self-transcendence; positive technology; neurofeedback; methods; attention; lucid dreaming; awe; altered states of consciousness

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Introduction

Defining Self-transcendence

The varieties of self-transcendence are vast, and self-transcendence relates to many similar concepts such as enlightenment, awakening, and mystical experiences. Self-transcendence is the extent to which a person identifies the self as an integral part of the universe as a whole. Moreover, self-transcendence is a changed perspective on the self in relation to other people, social status, material objects, one's own self-importance, and the sense of oneself as part of a greater whole (Levenson et al., 2005). Maslow (1969) has described self-transcendence as a person's ability to obtain a unitive consciousness with other humans. Similarly, Garcia-Romeu et al. (2015) defined self-transcendence as a kind of movement beyond the confines of the self to a larger whole of which the self is a part. Mossbridge (2016) extends these notions of self-transcendence as the experience of moving beyond the self and everyday perceptual and cognitive functioning to connect with others to also include coming to know an essential and pervasive truth. And, in the context of mindfulness, Vago and Silbersweig (2012) define self-transcendence as the development of a positive relationship between self and other that transcends self-focused needs and increases prosocial characteristics. From a nursing and end-of-life lens, self-transcendence is the capacity to expand self-boundaries intrapersonally (toward greater awareness of one's philosophy, values, and dreams), interpersonally (to relate to others and one's environment), temporally (to integrate one's past and future in a way that has meaning for the present), and transpersonally (to connect with dimensions beyond the typically discernible world) (Reed, 2013). While there seems to be some disagreement surrounding specific outcomes of self-transcendence such as prosociality and knowing a greater truth, it seems like Yaden et al. (2017) best capture the essence of all these definitions of self-transcendence as referring specifically to the aspects of decreased self-salience and increased feelings of connectedness to other people and one's surroundings.

Self-transcendence and Long-term Well-being and Positive Human Functioning

Defining Long-term Well-being and Positive Human Functioning

What does the term *well-being* mean? How can we know someone is *positively functioning*? Well-being or "being well" is not well defined. Calvo and Peters (2014) suggest that one draws on different theoretical lenses of well-being depending on the project. That said, the authors also state that for any project on well-being, it should be grounded in existing research and theory or else risk harm. Promotion of well-being advances supportive conditions and protective factors, whereas prevention of ill-being avoids risk factors. Prevention is the focus of our current medical model. The medical model can be useful in two ways: 1. clinical trails using CES-D and DSM-IV Global Assessment of Functioning (Clarke et al., 2001); 2. flip the measures to positive framing, researchers discovered 10 components of well-being, which include competence, emotional stability, engagement, meaning, optimism, positive emotion, positive relationships, resilience, self-esteem, and vitality (Huppert and So, 2013).

Subjective well-being, how one thinks they are doing in life, is generally comprised of life satisfaction, presence of positive mood, and absence of negative mood. A large body of research has used subjective well-being measures that have shown substantial validity through corroboration with neuroimaging, biological markers, and self-reports –for a review of subjective well-being and its measures see Diener (2000). Self-reports can either be online (as they occur in real-time) or recalled (as reported in a diary). Some researchers think recalled more accurately predicts future behaviour because of the act of reflecting over weeks, months, or years rather than reacting in the moment (Diener, 2000). In addition to self-reporting challenges, well-being is also affected by individual emotions, genes, physical health, and environmental factors; these can be studied through biology and neuroscience. Moreover, cultural differences in subjective well-being exist and it is important to consider a multidimensional model of well-being in order to better assess the underlying differences across nations. The Happy Planet Index, World Happiness Report, and Eurobarometer can all assess the difference across cultures.

From a theoretical standpoint, researchers have developed several well-being and positive human functioning models. **Positive psychology** was first introduced by Rogers (1961) and Maslow (1943). However, the empirical development of positive psychology was not fully realized until Seligman and Csikszentmihalyi (2000). Positive psychology operates on three levels:

1. subjective happiness, well-being, life satisfaction, love, hope, and optimization;
2. individual honesty, courage, future-mindedness, self-determination, forgiveness, originality, wisdom, interpersonal skills, and high talent;

3. group or societal creation and cultivation of meaningful positive relationships and positive institutions, and fostering those civic virtues for better citizenship, increased responsibility, altruism, tolerance of diversity, equality, opportunity, civility, reciprocity, and moderation.

This work on positive psychology was largely influenced by the author's previous work on flow theory and PERMA theory. Flow is the optimal experience of balance between high challenge and personal skill. Seligman (2002) developed the Authentic Happiness theory: pleasant life, engaged life, and meaningful life, but found that this theory had several limitations. Thus, he developed the PERMA (Positive Emotions, Engagement, Relationships, Meaning, and Achievement) model of well-being (Seligman, 2011), which combines emotional, psychological, and social well-being.

Another model of well-being, called **self-determination theory** (Ryan and Deci, 2000) postulates that autonomy, competence, and relatedness needs must be satisfied in order to foster well-being and health; and self-determined behaviour is intrinsically-motivated. Yet another well-being model is the **broaden-and-build hypothesis** (Fredrickson, 2001), where positive emotions broaden people's momentary thought-action repertoires, and positive emotions build over time enduring psychological, intellectual, physical, and social resources. Next, the **hedonic treadmill** concept says people get used to changes, either good or bad, and come back to a set point. It is important to note that this set point is generally positive and can be changed (Diener et al., 2009). **Hedonic** theories of well-being are focused on people's individual ideas on what makes a good life. On the other hand, **eudaimonic** theories of well-being use measures of how well an individual does on a set of factors that support well-being. Hedonic well-being is associated with stress response that promotes inflammation and decreases antibody production, whereas eudaimonic well-being increases antibody production (Fredrickson et al., 2013). Therefore, it seems like eudaimonic well-being is better for long term health.

The Relationship between Self-transcendence and Well-being

There exists quite a lot of evidence for well-being and positive human functioning being a correlate and outcome of self-transcendence –see reviews (McCarthy et al., 2018; Smith and Liehr, 2014; Yaden et al., 2017). I have grouped these well-being outcomes into four themes: Mental and Physical Well-being; Pro-sociality; Self-management; Life Quality and Satisfaction.

Mental and Physical Well-being

Self-transcendence can be comprised of positive emotions such as elevation, compassion, admiration, gratitude, love, and awe. And, these emotions have been linked to increased well-being (Fredrickson, 2009; Fredrickson et al., 2008; Keltner, 2009; Seligman, 2011). Peak ex-

periences, such as self-transcendence, have also been correlated with well-being (Margoshes and Litt, 1966; Mathes, 1982). In a study that looked at the relationship between well-being and self-transcendence, they found positive correlations between ego-transcendence and the predicted factors, including subjective well-being, psychological well-being, quality of life, and mindfulness (Zappala, 2007). Physically speaking, self-transcendence can promote receptivity to health messages and behaviour change in sedentary adults compared to controls (Kang et al., 2018).

A large portion of research in the area of self-transcendence and well-being comes from nursing, specifically late-life and palliative care (Smith and Liehr, 2014). In this context, self-transcendence is expressed through various behaviors and perspectives such as sharing wisdom with others, integrating the physical changes of aging, accepting death as a part of life, having an interest in helping others and learning about the world, letting go of losses, and finding spiritual meaning in life. Researchers have shown self-transcendence is both a correlate and contributor of well-being (Lundman et al., 2010; McCarthy, 2011; Reed, 2009; Teixeira, 2008). Researchers have discovered a positive relationship between self-transcendence and mental health in the elderly, i.e., 85 years and above (Nygren et al., 2005). A study of older women found an inverse relationship between depression and self-transcendence (Stinson and Kirk, 2006). And, in a study of late-stage Alzheimer's patients, they found self-transcendence correlated with well-being (Walsh et al., 2011). However, it is not only the oldest old that seem to benefit from self-transcendence. In a study of family caregivers for persons with dementia, they found poetry writing was an effective intervention that may promote positive outcomes such as achievement, catharsis, greater acceptance, empathy, self-awareness, reflection, creativity and fun, positive challenge, and helping others (Kidd et al., 2011). Moreover, a study with middle-aged persons found self-transcendence correlated negatively with depression and positively with acceptance (Ellermann and Reed, 2001).

Pro-sociality

One of the core components that defines self-transcendence is the connection to something beyond the self (Yaden et al., 2017). Pro-sociality includes all forms of empathetic and pro-social behavior that benefit others, such as sympathy, empathy, and altruism (Vago and Silbersweig, 2012). Altruism, or the selfless concern for the well-being of others, is correlated with a form of self-transcendence, elevation, or the feeling of moral uplift when viewing the virtuous action of another (Schnall et al., 2010). In fact, one study found those who experienced elevation compared to a control group were more likely to volunteer three months later (Cox, 2010). Similarly, Rudd et al. (2012) found that those who experienced awe, or deep feelings of wonder, astonishment, and sometimes fear were also more likely to volunteer to help others. In another study, awe predicted positive outcomes of increased generosity, ethical decision making, and pro-social values; this was attributed to feelings

of a small or diminished sense of self (Piff et al., 2015). Stellar et al. (2017) has argued that self-transcendent emotions, such as compassion, gratitude and awe, have emerged to help humans solve unique challenges related to group cooperation, coordination, and social interactions. Compassion training has also been shown to increase altruism (Leiberg et al., 2011; Weng et al., 2013). Moreover, compassion and social connection have been shown to increase happiness and resiliency in humans, contributing positively to their overall well-being (Seppala et al., 2013).

Empathy is often defined as "the act of perceiving, understanding, experiencing, and responding to the emotional state and ideas of another person" (Barker, 1999). Others have proposed empathy has four components: affective sharing, self-awareness, mental flexibility, and regulatory processes (Yoshiya and Jean, 2007). Empathy seems to be essential to communication (Calvo and Peters, 2014). By placing ourselves "in the shoes" of another, we might understand their experience in a way that goes beyond a simple processing or recognition of an others' emotion. Meditation training has been shown to increase empathy (Condon et al., 2013). Peak or intense personal experience have also been correlated with empathy (Olson et al., 1998; Wilson and Spencer, 1990).

Self-management

Several authors have noticed the improved self-regulation and self-care resulting from mindfulness-based interventions (for a review see (Baer, 2003)). Upchurch and Mueller (2005) have found that higher levels of self-transcendence are crucial for self-care engagement in elders. Davidson and McEwen (2012) have suggested that mindfulness interventions may promote self-control, emotional regulation, and improve later adult pro-social outcomes. Another mindfulness meditation study found that mindfulness significantly improved anxiety, depression, and pain after eight months; moderately improved stress and mental health-related quality of life; low or no effect for positive mood, attention, substance use, eating habits, sleep, and weight (Goyal et al., 2014). In the S-ART framework for understanding mindfulness (Vago and Silbersweig, 2012), attention regulation improves as attention effort decreases with time and practice of mindfulness. Emotional regulation is strengthened by mindfulness-based meditation practices, specifically evaluative, expressive and experiential aspects of emotion. Suffering is eliminated and maladaptive or distorted thinking and behaviours are transformed into more positive ones. Pro-social behaviour can take the form of dissolving the distinction of self and other and showing lovingkindness, which can lead to a greater sense of well-being and acceptance. Finally, decentering is being able to pivot to another perspective to observe oneself and, in doing so, gain insight. A correlational study that used the S-ART model found self-regulation mediated part of the effects of self-awareness on self-transcendence (Verhaeghen, 2018). Furthermore, they found self-preoccupation, self-compassion, self-transcendence, and controlled momentary sense-of-self,

all alleviated negative emotional states (stress, depression, and anxiety) and had a positive influence on psychological well-being.

Life Quality and Satisfaction

Researchers have shown the positive effects of transcendent experiences to support psychospiritual growth and maturity, bring life purpose, and change thinking and behaviour (Garcia-Romeu et al., 2015; Vago and Silbersweig, 2012). There is a growing body of empirical findings to support the role of self-transcendence in well-being including the adaptive benefits of religious and spiritual beliefs in finding ultimate meaning, mindfulness in attaining situational meaning, and goal striving in discovering one's calling (Wong, 2016). Magen (1996) have found that adolescents who realize positive experiences in greater depth and intensity also find a greater desire to help society and report they are more self-fulfilled. In another study, Coward and Kahn (2005) found women with breast cancer who bonded with each other led to further expansion of self-boundaries that brought comfort, a desire to modify life priorities, and enhanced appreciation of supportive others and of life itself. Matthews and Cook (2009) also studies patients with breast cancer and found self-transcendence alone mediated the relationship between optimism and emotional well-being.

In terms of quality of life, researchers have discovered nursing home patients (Haugan, 2014), homeless persons (Runquist and Reed, 2007), and those with Alzheimer's (Walsh et al., 2011) all improved with self-transcendence. An exploratory study on the effects of self-transcendence and proactive coping on successful aging, i.e., life satisfaction, found self-transcendence was the only significant contributor to this multidimensional view of successful aging (McCarthy et al., 2013); suggesting self-transcendence is an important variable in the process of successful aging and warrants more study. Overall, it seems like self-transcendence allows for a richer conceptualization of the meaning of life, and space for developing a self of purpose that extends to the world and not only to the self.

Research Questions

This thesis contributes to the design and evaluation of immersive experiences that support self-transcendence. In the pursuit of designing experiences around self-transcendence, it was necessary to first have a deep conceptual understanding of self-transcendence as well as the methodological approaches inherent in each construct. To this end, the first overarching research question is **how is self-transcendence conceptualized and measured in different research contexts? (RQ1)**. We approach RQ1 by further investigating two sub-questions:

RQ 1.1 What are the strengths and weaknesses of existing methods of measuring self-transcendence?

RQ 1.2 What are the suitability of methods of measuring self-transcendence given different conceptualizations?

Here we consider the conceptualization of self-transcendence as a state—a fluid or short-term mindset that is flexible in how you perceive the world; it is linked to a concurrent experience or transient mood. In this way, we can seek to understand how immersive technologies, like VR, might support or elicit the state of self-transcendence. Therefore, the second research question is **Do immersive environments support states of self-transcendence and, if so, how? (RQ2)** This question is explored through six sub-questions. In the first two sub-questions, we review the current literature to describe the design features most prevalent in immersive experiences related to self-transcendence:

RQ 2.1 How is self-transcendence supported in current immersive, interactive technologies?

RQ 2.2 What are the input and output modalities of immersive, interactive technologies that contribute to supporting states of self-transcendence?

I explore the remaining four sub-questions through two perspectives. The first considers lucid dreaming, a variety of self-transcendence that closely resembles the multi-reality nature of virtual reality. In this context:

RQ 2.3 In what ways is virtual reality like lucid dreaming?

RQ 2.4 What does this tell us about designing for self-transcendence in virtual reality?

In the second case study, we explore a virtual experience specifically designed to support the self-transcendent state of awe. Specifically, we explore whether the conditions surrounding a VR experience, that is the transitions into and out of VR, can better support the intended VR experience of awe compared to without thoughtfully designed transitions. We have two sub-questions:

RQ 2.5 Can the set and setting better support a profound emotional experience, such as self-transcendence?

RQ 2.6 If so, what are the important design features to support this experience?

Thesis Contributions and Overview

There are two main contributions in this thesis to both Psychology and HCI. The first is in providing a clearer understanding of the different methods of measuring self-transcendence considering different conceptual underpinnings (Chapter 1). The second is in designing and evaluating immersive experiences that support self-transcendence. I provide a review of the current state of immersive technologies that aim to support self-transcendence, extracting from that a set of design considerations for supporting self-transcendence (Chapter 2). Given that, I explore the potential immersive technology to support self-transcendence through two case studies: one that points to the value of set and setting surrounding an immersive experience (Chapter 5) and one that indicates that lucid dreaming is a potentially relevant

phenomenon for extracting design guidelines for self-transcendence in immersive technology (Chapters 3, 4, 6, 7). The following chapters are papers that are either submitted (7), accepted (1), or published (2, 3, 4, 5, 6).

Chapter 1. Measuring Self-transcendence: A Review on Research and Evaluation Methods for Investigating Self-transcendence

As I have discussed above, self-transcendence has a clear relationship to well-being, specifically increased positive emotions, behaviours, and perspectives on life; pro-sociality; self-management; quality of life; and life satisfaction. Despite the widely agreed upon benefits of self-transcendence, its conceptualization and measurement has proven difficult in the scientific field for various reasons including its introspective nature, spiritual connections, and multiple constructs. Therefore, in an attempt to better conceptualize and measure self-transcendence to move the research field forward, my colleagues and I have written a conceptual analysis where we review existing self-transcendence theories and measurements, and provide some recommendations for suitability of methods given research contexts. This will be presented as Chapter 1 of this thesis, and is currently accepted as a full paper in Frontiers in Psychology (Kitson et al., 2020a).

Chapter 2. Immersive Interactive Technologies for Positive Change: A Scoping Review and Design Considerations

Self-transcendence is increasingly becoming seen as beneficial, yet little research exists because it occurs in situations that are not very accessible to both the person wanting to experience it and the researcher wanting to study it. For example, many experiences of self-transcendence occur in nature, in vast spaces, and altered states of consciousness. Moreover, self-transcendence as a trait can change over the lifetime and one measure in time may not be an accurate reflection of that person's personality. Therefore, it is advantageous to find a way to support self-transcendence so that it can be more accessible both for people to experience and for researchers to study. One promising technology that can help support self-transcendence is virtual reality due to its ability to give people an immersive experience that has real-world psychological impacts, including its transformative potentials to manipulate bodily self-consciousness, embodying another's subjective experience, and alter laws of logic and nature. Yet, there are currently no existing principles to guide the design of self-transcendent experiences in virtual reality. In order to better understand the state of art in virtual reality design for supporting self-transcendence, my colleagues and I reviewed existing research and identified the most prominent design features and interaction strategies. From this scoping review, we used a inductive approach to derive a conceptual framework and design considerations for virtual reality in supporting self-transcendence. This will be presented as Chapter 2 of this thesis, and is currently published as a full paper in Frontiers in Psychology (Kitson et al., 2018a).

Chapter 3. Can Lucid Dreaming Research Guide Self-transcendence Experience Design in Virtual Reality?

The design insights from our scoping review above were helpful in understanding what has been done before and summarized the collective knowledge of designing for self-transcendence in virtual reality from multiple perspectives. That said, the scoping review was limited in giving a definitive answer to our research question because this is an emerging research topic and not much work is done. Moreover, the quality of the included studies was, in general, not as high as typically required for a systematic review; we included even proof-of-concept designs because of the scarcity of virtual reality experiences specifically designed for supporting self-transcendence. Therefore, in order to have more robust design guidelines, we decided to complement this approach by also taking an inductive approach by grounding our design guidelines in human experience. We decided to use lucid dreaming as our base in which to ground design guidelines for self-transcendence in virtual reality because of the parallels between the both lucid dreaming and self-transcendence and lucid dreaming and VR. Lucid dreaming is associated with positive transcendent emotions such as awe and love, mystical and spiritual experiences, meditation, and introspection. Lucid dreaming has often been viewed as the "ultimate virtual reality" because of the knowledge one is in a non-ordinary reality and at the same time feel like they are there in that reality, and one is able to essentially do whatever they want including live out fantasies that are not possible in waking life. I further elaborate on these parallels and argue for using lucid dreaming to guide the design of self-transcendence in virtual reality. This will be presented as Chapter 3 of this thesis, and is currently published as an extended abstract in the 2018 IEEE Workshop on Augmented and Virtual Realities for Good (Kitson and Riecke, 2018).

Chapter 4. Are You Dreaming? A Phenomenological Study on Understanding Lucid Dreams as a Tool for Introspection in Virtual Reality

In the above paper, I have argued that spiritual experiences like lucid dreaming can provide us with rich data on how to better design for self-transcendence in virtual reality because of their strong parallels to each other and potential for self-transcendence. Lucid dreaming has strong roots in spiritual practices such as dream yoga in Tibetian Buddhism and Vipassana meditation, which are facets of self-transcendence. Moreover, compared to non-lucid dreamers, lucid dreamers report having greater positive emotions upon waking that are described as self-transcendent emotions such as awe, sublime, love, gratitude, and compassion. In order to derive design considerations using an inductive approach, I performed phenomenological interviews with proficient lucid dreamers. This will be presented as Chapter 4 of this thesis, and is currently published as a full paper in the 2018 CHI Conference on Human Factors in Computing Systems (Kitson et al., 2018b).

Chapter 5. Designing Mind(set) and Setting for Profound Emotional Experiences in Virtual Reality

With these design considerations in mind, derived from both the inductive scoping review and the inductive phenomenological interviews, we sought to test them in two specific case studies. We decided on two case studies in order to explore the relationships between two different connections: self-transcendence and virtual reality (in Chapter 5); lucid dreaming and virtual reality (in Chapters 6 and 7). It is important to distinguish between the two since there is still little evidence, although promising, that virtual reality is like lucid dreaming and that virtual reality can support self-transcendence. We will compare and contrast the two case studies to see how experiences of lucid dreaming in VR relate to experiences of self-transcendence in VR.

There were several overlapping design features in both papers above (3 and 4), yet one that stood out in only the phenomenological study was the idea of using ceremony to "set the tone" for the experience. Indeed, mindset and setting are often overlooked in quantitative research studies in virtual reality. Since we are interested in designing for supporting self-transcendence–a profound, intimate, emotional phenomena–the mindset and setting seems like it would be important in helping to support that experience. Thus, the first case study was to explore how our design considerations, particularly mindset and setting, might support self-transcendence in virtual reality. The specific virtual reality experience was designed around the self-transcendence concept of awe–a complex emotion characterized by intense feelings of astonishment, wonder and connectedness that arises when one is confronted with something vast that transcends previous knowledge schemas. We had participants try the AWE virtual reality experience either with or without an additional mindset and setting design, and interviewed them about their experiences as well as perform behavioural tasks related to outcomes of awe. This will be presented as Chapter 5 of this thesis, and is currently published as a full paper in the 2020 DIS Conference on Designing Interactive Systems (Kitson et al., 2020b).

Chapter 6. Lucid Loop: A Virtual Deep Learning Biofeedback System for Lucid Dreaming Practice

The second case study was to explore how the design considerations implemented as a lucid dreaming-like experience might be reminiscent of what lucid dreamers actually experience. Essentially, we wanted to put the design considerations into practice and further explore what design features might be important for supporting self-transcendence in virtual reality. To achieve this, we designed an immersive experience, Lucid Loop, around two self-transcendence concepts: the focused attention facet of mindfulness and the altered state of consciousness facet of mystical experience. This will be presented as Chapter 6 of this thesis, and is currently published as an extended abstract in the 2019 CHI Conference on Human Factors in Computing Systems (Kitson et al., 2019).

Chapter 7. An Exploratory Study on an Immersive Environment and Neurofeedback System with Modified Deep Dream 360 Video to Support Lucid Dreaming Practices

Taking our design of Lucid Loop (in Chapter 6) further, we conducted a qualitative study with nine proficient lucid dreamers to try a neurofeedback-based immersive environment that utilizes 360 video and audio in a head-mounted display (HMD) device for lucid dream training. Participants reported their experiences in a cued recall debrief interview. The results show the similarities between lucid dreaming and Lucid Loop, indicating immersive environments' usefulness for training lucid dreaming because of its capacity for emotionality and fluidity between self and environment. Participants experienced a tension between simply noticing and wanting to control how their brain waves influenced the environment through neurofeedback. This will be presented as Chapter 7 of this thesis, and is currently submitted as a full papers to the 2021 CHI Conference on Human Factors in Computing Systems.

Chapter 8. Discussion and Conclusion

In the final chapter, Chapter 8, I discuss the overall contributions of this thesis, the main conclusions, and an outlook on future research. While self-transcendence may at first appear an unconventional topic of scientific inquiry, laced with mysticism and spirituality, there is much wisdom to be had if we step outside the traditional cause-and-effect paradigm and embrace the unseen, unexplored, and misunderstood aspects of human experience.

Chapter 1

A Review on Research and Evaluation Methods for Investigating Self-transcendence

This chapter is accepted in Frontiers in Psychology (September 30, 2020).
Kitson, A., Chirico, A., Gaggioli, A., and Riecke, B. E. (2020). A Review on Research and Evaluation Methods for Investigating Self-transcendence. *Frontiers in Psychology: Consciousness Research*. doi: `https://doi.org/10.3389/fpsyg.2020.547687`

1.1 Abstract

Self-transcendence has been characterized as a decrease in self-saliency (ego disillusionment) and increased connection, and has been growing in research interest in the past decade. Several measures have been developed and published with some degree of psychometric validity and reliability. However, to date, there has been no review systematically describing, contrasting, and evaluating the different methodological approaches towards measuring self-transcendence including questionnaires, neurological and physiological measures, and qualitative methods. To address this gap, we conducted a review to describe existing methods of measuring self-transcendence, evaluate the strengths and weaknesses of these methods, and discuss research avenues to advance assessment of self-transcendence, including recommendations for suitability of methods given research contexts.

1.2 Introduction

Self-transcendence is often defined as decreased self-saliency and increased connection to others and the environment (Yaden et al., 2017a). However, if we look across different disciplines, we find the focus and conceptualization of self-transcendence varies. For example, psychologists often view self-transcendence as involving an elevation or a separation of self from the environment, whereas nursing regards self-transcendence as aware-

ness of one's wholeness in person–environment connections when fragmentation threatens one's well-being (Smith and Liehr, 2014). Self-transcendence seems to be emerging in several disciplines including nursing theory, developmental psychology, gerontology, personality theory and psychiatric genetics, positive psychology, and others (Garcia-Romeu, 2010). Self-transcendence can be regarded as a psychological state, personality trait, developmental process, value orientation, motivation, and worldview (Wong, 2016). Self-transcendence experience is also considered multifaceted in itself, composed of mindfulness, flow, self-transcendent emotions, awe, peak experiences, and mystical experiences (Yaden et al., 2017a). Therefore, depending on the discipline and focus, one will find very different approaches to investigate the phenomenon of self-transcendence (Garcia-Romeu, 2010). Nonetheless, here we will review and describe the research and evaluation methods across different disciplines for investigating self-transcendence by critically discussing, comparing and evaluating them.

Our goals for this paper are to (1) describe existing methods of measuring self-transcendence; (2) evaluate the strengths and weaknesses of these methods; (3) discuss research avenues to advance assessment of self-transcendence, including recommendations for suitability of methods given research contexts.

1.3 Theories of Self-transcendence

There exist several theories on self-transcendence, which I divided into three categories: conceptual, phenomenological, and physiological. Each offer a different perspective into understanding self-transcendence since the construct itself is not widely agreed upon.

1.3.1 Conceptual

Frankl (1966) is perhaps one of the first researchers to go against Freudian models of pleasure seeking and equilibrium as our sole drivers and goals, and toward a model of self-transcendence. Here, Frankl's self-transcendence construct emphasizes focusing on serving others and not on fulfilling one's own potential through constant self-referral. A more contemporary model of self-transcendence uses Frankl's construct and describes it on three levels (Wong, 2016):

1. Seeking ultimate meaning —seeking ultimate ideals of goodness, truth, and beauty;
2. Seeking situational meaning —mindful of present moment with openness, curiosity, and compassion;
3. Seeking one's calling —pursue higher purpose for the greater good.

Another key theory that is relevant to today's conceptualization of self-transcendence is Maslow (1943)'s hierarchy of needs (from bottom to top): physiological (survival) through

basic life necessities; safety and security through law and order; belongingness and love through group affiliation; esteem through recognition and achievement; self-actualization through fulfillment of personal potential. Theorists postulate there is a sixth tier need—self-transcendence (Venter, 2017). Maslow wanted to show there is a false dichotomy of thinking of the world as only the self and the environment. One who has self-transcendended no longer relies on others' opinions and is free from culture and social environment. Self-transcendence is being no longer grounded or anchored in one's own culture alone; not exclusively defined by their immediate environment or group. Through self-transcending culture, one can better identify with others. Stellar et al. (2017) and Haidt and Morris (2009) also supported the idea that self-transcendent emotions —compassion, awe, gratitude, appreciation, inspiration, admiration, elevation, and love —are key to positive social functioning and connecting to others. For example, compassion helps to support those in need; gratitude builds commitment to others in need; awe reduces self-importance.

As a way to conceptualize self-transcendence, some have suggested self-transcendence is a measurable personality trait that captures the degree to which an individual feels a part of nature and the universe at large (Cloninger et al., 1993). Four traits predictive of self-transcendence were neuroticism (negatively correlated), openness to experience (positive), agreeableness (positive), and conscientiousness (positive); another predictor variable was meditation practice (positive) (Levenson et al., 2005). Others have derived components of self-transcendence from the aging process and development across the lifespan, otherwise known as *gerotranscendence* (Tornstam, 1994). Yaden et al. (2017a) posit the following constructs for self-transcendence: mindfulness, flow, positive emotions (elevation, compassion, admiration, gratitude, love, awe), peak experiences (e.g., comic consciousness, merging with the universe), mystical experiences (e.g., psychedelic), pathological experiences (e.g., schizophrenia, depersonalization disorder). The authors suggest that self-transcendent experiences contain two sub components: reduced self-saliency (annihilation component) and increased connectedness (relational component). Furthermore, blurring the lines between social and spatial (culture and environment) may be a way to increase perceived social connection and, thus, increase well-being. From Yaden et al. (2017a)'s perspective, self-transcendent experiences do not seem to serve any individualistic evolutionary purpose, but might be seen as a way to reinforce cohesive social groups. Additionally, they are also not well understood in terms of efficacy, contraindications, and implications for therapeutic purpose.

A highly related construct of self-transcendence is meditation, especially those practices that follow the dissolution of self, time, and external reality. As described in Yaden et al. (2017a) and detailed in Vago and Silbersweig (2012), cultivating a state of mindfulness leads to the development of self-other relations that transcends selfish needs, described in the literature as "decentering". In advanced mindfulness practitioners, this self-other distinction is completely dissolved (Vago and Zeidan, 2016). Dorjee (2016) describes a con-

templative practice framework that outlines the progression in shifts of self and reality as states associated with increasing gradients of dereification. Here, the decentering aspect of mindfulness-based practices has been linked to the initial stages of this progression. Schoenberg and Vago (2019) outline a multi-dimensional model of meditation that progresses in five stages: (1) relaxation practices characterized by neuro-visceral processes; (2) concentration practices characterized by focused and diffuse attention; (3) insight practices characterized by ordinary insight that all objects are illusory or constructs of the mind; (4) non-dual practices characterized by dissolution of the self and everything; (5) cumulative practices characterized by unifying compassion and unconditional love as outcomes of the previous four practices. Self-transcendence in particular seems to relate to the latter stages of this model where the ego is dissolved and meditation practitioners experience a feeling of unity. This concept of different developmental-stages in meditation is echoed in Piron (2001)'s paper on meditative depth, which defines meditation not only in type but also in terms of level felt during different times, i.e., a person can experience different degrees of self-transcendence at different times in their life. Piron (2001) refers to Engel (1997)'s Meditation Development Index (MDI) measure that is based on Engel (1997)'s Zen developmental theory of meditation comprised of eight stages: (0) premeditative: meditation as tranquilizer; (1) searching: uncertainty and disorientation; (2) effort: struggle, fight; (3) level of work: calm, regular exercises; (4) support: pleasantness and motivation to continue; (5) being uplifted; (6) resolution; and (7) afterwards. Piron (2001) then furthered MDI by constructing both the Meditation Depth Index (MEDI) and Meditation Depth Questionnaire (MEDEQ) to measure the greatest depth of meditation and meditation itself in a more differentiated way than the index, respectfully.

Millière et al. (2018) approaches self-transcendence as a multidimensional model of altered self-consciousness. They describe self-consciousness as dissolving the sense of self through meditation and the phenomenon occurring from drug-induced ego-dissolution. Here, self-consciousness is organized into two categories of narrative and embodied selfhood. These two aspects are then plotted against six dimensions: (1) a sense of body ownership, (2) awareness of bodily sensations, (3) awareness of spatial self-location, (4) rich phenomenology, (5) access to semantic autobiographical information, and (6) self-related thoughts. A total loss of self is then the absence of these dimensions for both the narrative and embodied self. The authors have emphasized that self-consciousness is not a simple nor uni-dimensional construct, showing that different forms of meditation and psychedelic states are mapped differently to their multidimensional model.

Nursing's conceptual idea of self-transcendence is "the capacity to expand self-boundaries in a variety of ways" (Reed, 2013). In forming this concept of self-transcendence, nurses drew from Neo-Piagetian theories about development in adulthood and later life. The model itself is composed of four basic sets of relationships (Figure 1.1). First, increased levels of vulnerability, e.g., health event, influence increased levels of self-transcendence. Reed describes

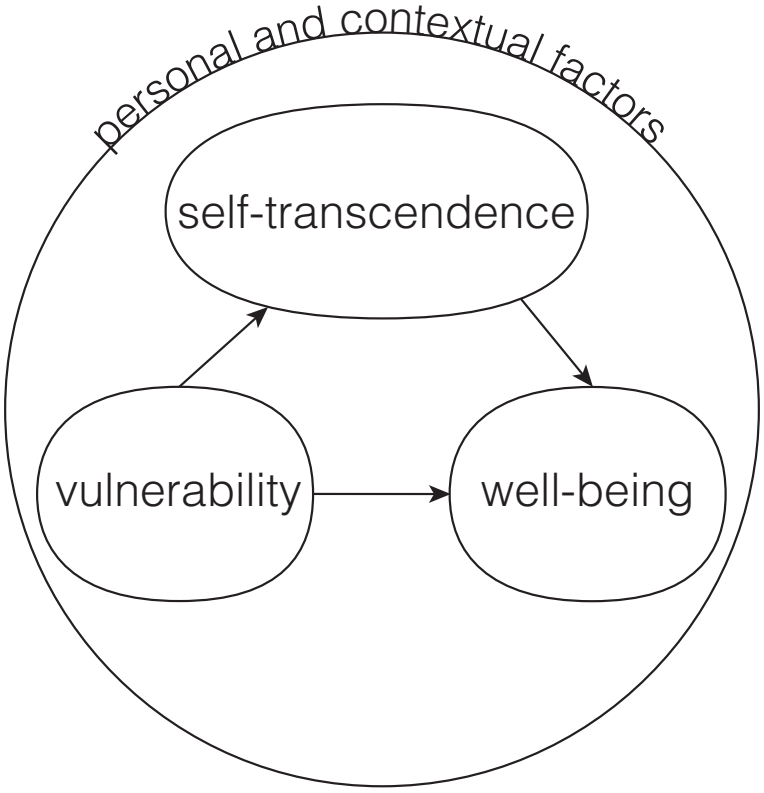

Figure 1.1: Model of Self-transcendence in the context of nursing described in Reed (2013).

vulnerability here as the awareness of one's own mortality, and that self-transcendence arises naturally from this awareness that is often triggered by life crises. Second, self-transcendence relates positively to a sense of well-being and morale but relates negatively to the level of depression. Third, self-transcendence mediates the effects of vulnerability on well-being. Fourth, personal and contextual factors play a role in all three variables, e.g., age, gender, cognitive ability, health status, past significant life events, personal beliefs, family support, and sociopolitical environment. Another conceptual model of self-transcendence from nursing is based on a literature review and uses the process of concept analysis (McCarthy et al., 2018). The antecedents and attributes of self-transcendence are organized into five logically related domains: creativity, relationships, introspection, contemplation, and spirituality (Figure 1.2).

1.3.2 Phenomenological

There is a large body of theoretical literature and empirical research on self-transcendence. However, some of the conceptual models of self-transcendence mentioned above have had their internal validity questioned (MacDonald and Holland, 2002), suggesting that in when reporting self-transcendence an individual might not be able to separate core constructs;

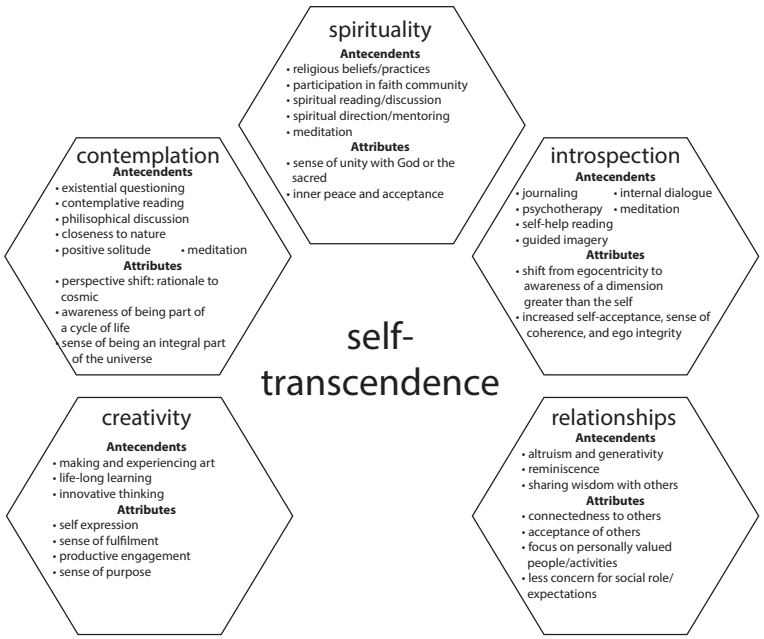

Figure 1.2: Conceptual model of self-transcendence described in McCarthy et al. (2018). This model was originally used for the Psychoeducational Approach to Transcendence and Health (PATH) program on self-transcendence and well-being in community-dwelling older adults.

and the construct of self-transcendence itself needs further analysis (Akyalcin et al., 2008). There is less research on the process, outcomes, and nature of self-transcendence itself.

Garcia-Romeu et al. (2015) used a grounded theory approach to address shortcomings in the current understanding of self-transcendence in the experiential domain. In terms of context, self-transcendence likely occurs during stressful or challenging times in life, in adulthood, during religious/spiritual practices or social events like concerts/raves, and is catalyzed with psychoactive drugs, spiritual instruction, dance, and prayer. In terms of phenomenology, self-transcendence is described as very physical, whether that be warmth, connectedness, lightness, vibration or shaking, hyper-ventilating, nausea, and vomiting. Perceptually, there is an expansive change in self-boundaries, egolessness, and timelessness. Cognitively and affectively, participants experienced positive affective states (e.g., joy, love, compassion, forgiveness, wonder, and freedom), surrender, vulnerability, and openness. Many people revealed that words and the vehicle of the mind could not really explain their self-transcendent experience because the experience itself transcended such boundaries. In terms of aftermath, the short-term effects consisted of mainly decreased anxiety, increased energy, insight, socialability, and sustained positive affect. Long-term effects were related to enduring transformation and impact, i.e., worldview, self-concept, and value-orientation. The outcomes for aftermath were value re-orientation, increased concern for others, increased positive affect, and disidentification from old patterns of thinking or behavior. The

authors recommended self-transcendence needs more research on the pathological manifestations and its potential role in promoting enhanced well-being.

Metzinger (2020) proposed nondual awareness as a non-conceptual, minimal phenomenal experience. Nondual awareness or consciousness-as-such is a highly related to self-transcendence, described by Josipovic (2019) as "an empty cognizance, aware and present, but without any thoughts, emotions or perceptions, without a sense of body, space, orientation, time or the usual sense of self" (p. 279). In other words, nondual awareness is where the self and world are merged into a unified whole or the boundaries of the self are dissolved (Gyamtso, 2001). Nondual awareness occurs during states of lucidity in sleep and absorption in meditation (Thompson, 2010).

Nour et al. (2016) conceptualize self-transcendence in the same way as Yaden et al. (2017a)—a disappearance of the sense of self. Nour et al. (2016) describe ego consciousness as having two main constructs. First, ego-dissolution as "the associated feeling of increased union with one's surroundings, known as dissolved ego-boundaries". Second, ego-inflation as "the distinct and largely antithetical experience of unusually elevated self-assuredness and confidence". Thus, self-transcendence would then be the presence of ego-dissolution and absence of ego-inflation.

1.3.3 Physiological

Much of the neurophysiological research on self-transcendence relates to meditation and specifically mindfulness meditation, since, according to some, one component of mindfulness is self-transcendence (Vago and Silbersweig, 2012). There is also research on the neural correlates of experiences that are under the umbrella of self-transcendence such as awakening, enlightenment, and mystical experiences. We describe these studies as they relate to self-transcendence but there are always limits when the construct of self-transcendence highly varies across studies. For an overview of neurological and biochemical underpinnings of self-transcendence, see Figures 1.3 and 1.4.

In studying *awakening experiences*, which de Castro (2017) describes as a transcendent experience or "an essential core experience of oneness", he presents a model that postulates three processing layers: sensory, perceptual, and cognitive. An awakening experience occurs when these three layers are removed. Testing this model is challenging since scientific methods are difficult to apply to phenomena that cannot be reliably and repeatedly produced. Nevertheless, de Castro (2017) sought the specific neurophysiological underpinnings of self-transcendence by comparing his model to existing research. First is the default mode network (DMN), which consists of the medial temporal lobe (declarative or long-term memory), medial prefrontal cortex (analyzing and thinking about attributes of other individuals), posterior cingulate cortex (autobiographical memory), and the ventral precuneus (hub of DMN) as well as parts of the parietal cortex (proprioception) (Smallwood et al., 2012). DMN activity is reduced during contemplative practice, such as meditation

(Berkovich-Ohana et al., 2013b; Garrison et al., 2014; Hasenkamp and Barsalou, 2012), as well as in one study showing a video of awe (van Elk and Rotteveel, 2019). This suggests that contemplative practice reduces activity in neural structures involved in cognitive processing. This restraint on the cognitive system in turn amplifies the perceptual and sensory systems. In fact, those brain areas related to perceptual and sensory systems were larger in meditators and cognitive brain areas were smaller (Fox et al., 2014). Specifically, Fox et al. (2014) found these meditation brain areas increased in size: rostrolateral prefrontal cortex (metaawareness and introspection), sensory and insular cortices (body awareness), and anterior, mid-cingulate, and orbitofrontal cortex (emotion regulation). Moreover, these DMN areas were reduced in size: posterior cingulate cortex (self-related thinking), angular gyrus (transfers visual information to Wernicke's area), precuneous (self-awareness), and temporoparietal junction (self-other distinctions). Second, lesion studies have also looked at how self-transcendence is affected pre- and post-surgery and found that damage to the posterior parietal lobe, which is related to body sense and bodily interrelationships, increased self-transcendence (Johnstone et al., 2012; Urgesi et al., 2010). Third, transcranial magnetic stimulation (TMS) of inferior parietal lobe, related to body perception and separation of the environment, increases religiousness and spirituality (Crescentini et al., 2016). Other methods for eliciting self-transcendence are direct electric stimulation of brain regions (Blanke et al., 2002, 2004) or transcutaneous vagus nerve stimulation (Finisguerra et al., 2019). Finally, psilocybin has been found to produce reliable effects indistinguishable from awakening experiences; shows decreased DMN and feelings of oneness. Some researchers have looked at studying individuals who can have transcendent experiences regularly, but this method has its flaws (see Davis and Vago (2013)). Another approach is to develop adequate model test conditions, i.e., better experimental procedures for evoking awakening experiences, such that we can better define the model.

Davis and Vago (2013) outline whether we can determine the specific neural correlates for *enlightenment*, a term often equated with awakening in Buddhist traditions. The short answer: no. They argue measuring enlightenment is not possible because it is too vaguely defined as a construct. There is too much disagreement, even within Buddhist traditions, on what states and traits define enlightenment over mere concentration. Even if they are agreed upon, people may not agree on whether that state was achieved or not. Even Buddhist teachers do not accept self-reports of meditation experience at face value, but rather assess practice history, the manner and emotional state the report is given, and retrospective observations of behaviour. Despite these concerns and challenges, Davis and Vago (2013) offer a potential solution by integrating evidence from neuroimaging with evidence of behavioural transformations specified in particular traditional descriptions of meditation practice. To this end, neuroimaging techniques have shown potential neural correlates of enlightenment. Cessation, referring to cessation of all inward phenomena in meditation, is linked to increased activity in the frontal polar cortex or Brodmann area-10 (higher cog-

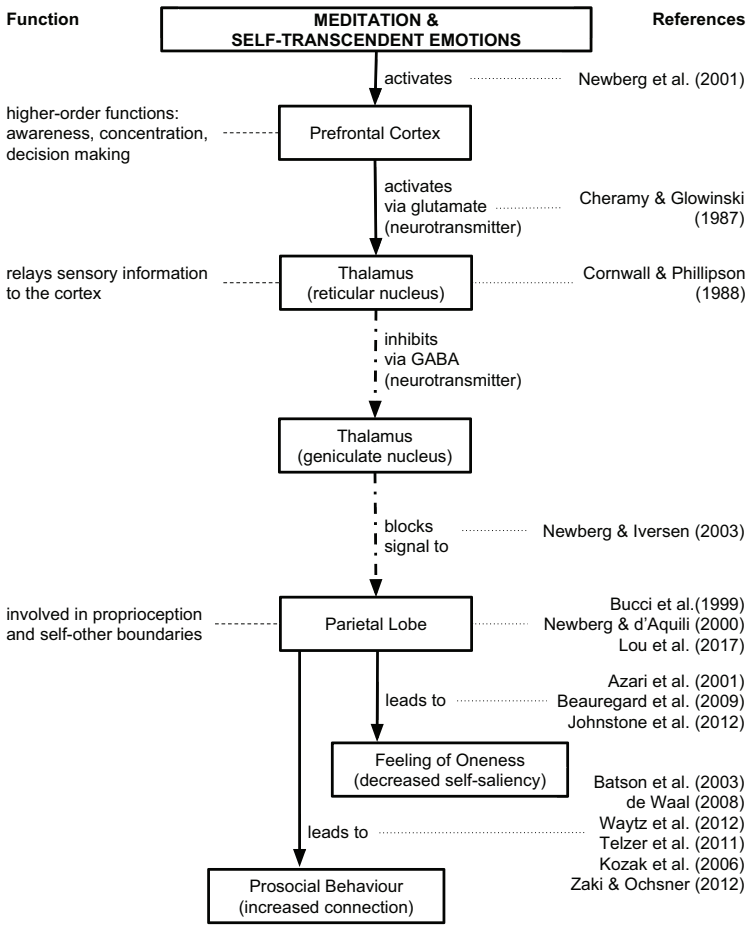

Figure 1.3: Neurological processes relating to self-transcendence. For a review, see (Newberg, 2014; Yaden et al., 2017a,b).

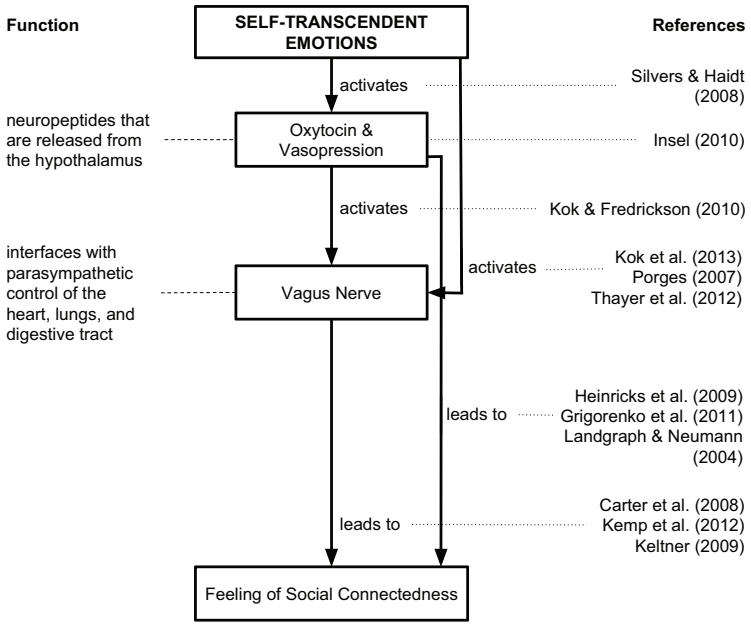

Figure 1.4: Biochemical processes related to self-transcendence. For a review, see (Yaden et al., 2017a).

nitive functioning) (Koechlin et al., 1999; Ramnani and Owen, 2004). However, there are limitations with fMRI because it relies on generalized linear modelling, which carries some assumptions that a low-resolution fMRI signal, state bleed-over, and subtle states of enlightenment might violate. EEG found gamma band power over the lateral frontal and parietal sites correlated with self-reported clarity in meditation practitioners, suggesting a particular mechanism for increased phenomenal intensity (Lutz et al., 2004).

In terms of the Self-Awareness, -Regulation, -Transcendence (S-ART) model, where "T" represents the self-transcendent aspect of mindfulness, there are brain regions for self-specifying (i.e., experiential enactive self and experiential phenomenological self) and self-related processes: the dorsal attentional system and hippocampal-cortical memory system (Vago and Silbersweig, 2012), both components of the DMN. The S-ART framework suggests mindfulness critically involves working memory, efficiency of memory encoding, retrieval, and extinction processes, all aspects of hippocampal and parahippocampal activity, which serve higher order cognitive functions. This relates back to de Castro (2017)'s model of awakening experience, suggesting a common mechanism behind these types of experiences.

One review on the psychological and neurobiological mechanisms that may mediate the effects of self-transcendence comes from Yaden et al. (2017a), who conceptualize self-transcendence as having two major components: loss of self and increased connectedness. In terms of the loss of self, they found superior and inferior parietal functioning is associated with representations of the body's state (i.e., self and other representations) (Newberg

et al., 2001), and is decreased when people report having a mystical experience (Azari et al., 2001; Beauregard and Paquette, 2006; Johnstone et al., 2012). Lesions in parietal regions lead to disassociation with the self and out-of-body experiences (Urgesi et al., 2010). Thus, a self/other overlap may also relate to the pro-social qualities of self-transcendence. In terms of the increased connectedness, neurological correlates might be oxytocin and arginine vasopressin, which are associated with social connection (Grigorenko, 2011; Heinrichs et al., 2009; Landgraf and Neumann, 2004). However, the research on these neuropeptides is based on animal models, so the validity of these claims for humans is limited. Researchers also found the vagus nerve is activated during self-transcendent positive emotions such as awe, compassion, gratitude, and love (Keltner, 2009; Kok and Fredrickson, 2010; Kok et al., 2013; Thayer et al., 2012). The vagus nerve is a cranial nerve that interfaces with parasympathetic control of the heart, lungs, and bladder. Since a parasympathetic response is associated with a sedative state, the vagus nerve activation would decrease under "stress" and increase when the body is at rest or in a peaceful state, which could be associated with positive emotions such as self-transcendence.

While we have described a simplified model of the neurological processes related to self-transcendence in Figures 1.3 and 1.4, a more comprehensive model is suggested by Newberg and Yaden (2018). These authors have put forth a recent review on the brain processes involved with altered-states of consciousness, which they define as a type of self-transcendent experience "associated with intense experiential components and are frequently interpreted in reference to religious and/or spiritual concepts". Their model shows these major brain areas likely involved in altered-states of consciousness including the prefrontal and anterior cingulate cortex, the thalamus, the parietal lobe, the hippocampus and amygdala, as well as the hypothalamus and autonomic nervous system.

1.4 Literature Search Methods

We conducted a literature search using ACM, IEEE, and ProQuest databases to identify relevant research articles. We performed additional hand searches of references in the retrieved literature. Our search for studies tapping into the measurement of self-transcendence included articles and empirical work published until September 1, 2019. The search strategy considered only studies published in English. Primary search terms were "self-transcendence", "mindfulness", "flow", "self-transcendent positive emotions", "awe", "peak experiences", "mystical experiences", "altered states of consciousness and transcendence" plus "measurement", "assessment", "questionnaire". Secondary search terms included self-transcendence and the name of the scale spelled out or abbreviated. We excluded measures that did not fit the definition of self-transcendence as "a feeling of decreased self-saliency and increased connection".

1.5 Results: Research/Evaluation Methods for Investigating Self-transcendence

Methods of investigating self-transcendence can be divided into five major categories: questionnaires and surveys; diary and journal entry; interviews; neurological and physiological measures; and behavioural measures. Next, we will evaluate and discuss these methods with reference to the table in the supplementary materials.

1.5.1 Questionnaires and Surveys

Many attempts have been made to capture the subjective nature of self-transcendence through self-report questionnaires. Defining self-transcendence is of utmost importance because, of course, we cannot compare results if researchers are using different definitions. On the other hand, self-transcendence can be looked at as having several facets; studying these different facets could be a way of looking at self-transcendence from multiple lenses, e.g., Yaden et al. (2017a). Next, we briefly describe questionnaires for each of these facets, and we further discuss the validity and reliability in Section 1.6.2.

1.5.1.1 Mindfulness Questionnaires

Mindfulness questionnaires can be divided into two different categories: state and trait. State mindfulness is a fluid or short-term mindset that is flexible in how you perceive the world; it is linked to a concurrent experience or transient mood. Trait mindfulness, on the other hand, is a more permanent facet of personality, most likely linked to genetics. A state, when repeatedly elicited, can often result in a trait change (Kiken et al., 2015). Most mindfulness questionnaires are aimed at assessing trait mindfulness: Mindful Attention Awareness Scale (MAAS) (Brown and Ryan, 2003), Freiburg Mindfulness Inventory (FMI) (Buchheld et al., 2001), Kentucky Inventory of Mindfulness Skills (KIMS) (Baer et al., 2004), Cognitive and Affective Mindfulness Scale (CAMS-R) (Feldman et al., 2006), Southampton Mindfulness Questionnaire (SMQ) (Chadwick et al., 2008), and Five-Facet Mindfulness Scale (FFMQ) (Baer et al., 2006). Capturing one's ability to get into a state is challenging, and there are different approaches. One approach is by using several facets to capture mindfulness. FFMQ and KIMS both have multiple facets to measure mindfulness, and report good internal consistencies, $\alpha = .89$ and $.76 - .91$ respectfully. However, despite their perceived comprehensiveness, researchers have found the multiple sub-scales provide redundant information and the time to complete the surveys is long. MAAS, FMI, and CAMS-R all purposefully have one total score because the researchers believe mindfulness is comprised of many things that cannot be separated out into sub-scales. MAAS is the mostly widely used mindfulness scale, with an internal consistency of .82, test-retest reliability of 0.81, and adequate convergent and discriminant validity. FMI is the second most widely used mindfulness scale, but unlike MAAS it includes a focus on curiosity as a part of the definition

of mindfulness; FMI has an internal consistency of .93. CAMS-R is the shortest holistic measure of mindfulness with only 12 items. Internal consistencies ranged from $.74 - .80$. Lastly, SMQ is different from all the other scales because it measures a mindful approach to distressing thoughts and images. SMQ has an internal consistency $\alpha = .89$; significant correlation with MAAS $r = .57$.

There exist only two mindfulness questionnaires that aim to measure state mindfulness: State Mindfulness Scale (SMS) (Tanay and Bernstein, 2013) and Toronto Mindfulness Scale (TMS) (Lau et al., 2006). TMS contains two sub scales, curiosity and decentering, with internal consistencies of .93 and .91, respectively. SMS has also shown a high reliability of $\alpha = .95$. While TMS seems to be more widely used, it is intended for meditators, so languages used may not be accessible to novices. SMS, on the other hand, was designed to be used with all levels of mindfulness meditation and does not use jargon terms.

Another questionnaire that aims to measure meditation regardless of practice type, i.e., mindfulness or otherwise, is the Meditation Depth Questionnaire (MEDEQ) (Piron, 2001). MEDEQ is widely used because of its meditation practice agnostic quality and has good convergent validity ($.64 - .93$) as well as high internal consistency ($\alpha = 0.92$).

1.5.1.2 Flow Questionnaires

Flow seems to be assessed mostly in the context of either games or physical activity. While many designers and developers aspire to flow, few actually have a scientifically valid and reliable way to measure it. Csikszentmihalyi (1990) started to develop the Flow Scale using semi-structured interviews, but that scale did not seem to have high reliability estimates. Jackson and Marsh (1996) have developed two separate scales to measure flow, based off of Csikszentmihalyi's flow theory: Flow State Scale (FSS) (Jackson and Marsh, 1996), Flow State Scale 2 (FSS-2) and Dispositional Flow Scale 2 (DFS-2) (Hamari and Koivisto, 2014; Jackson and Eklund, 2002). These scales are very similar in the questions they ask and their theoroetical underpinnings, with similarly strong content and construct validity and reliability estimates ranging from $.81 - .90$. The difference is in the application: FSS measures flow experienced within a particular event and DFS measures the frequency of flow experiences in a given event in general.

1.5.1.3 Self-transcendent Positive Emotions and Awe Questionnaires

Positive emotions might be assessed using popular emotion scales such as the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988), Self Assessment Manikin Scale (SAM scale) (Bradley and Lang, 1994), or International Affective Picture System (IAPS) (Lang et al., 1997). However, these do not focus on the specific positive emotions relating to self-transcendence, namely elevation, compassion, admiration, gratitude, love, and awe. There exist three scales that attempt to capture these emotions: Inclusion of Other in Self Scale (IOS) (Aron et al., 1992), Dispositional Positive Emotion Scales (DPES) (Shiota

et al., 2006), and Modified Differential Emotions Scale (mDES) (Fredrickson et al., 2003). IOS uses a set of Venn Diagrams to assess self-other overlap with good test-retest reliability ($r = .83$ overall), and good convergent, discriminant, and predictive validity. DPES assesses seven different positive emotions that are closely related to self-transcendence, with good reliability estimate ranging from $.75 - .92$. However, DPES does not assess positive emotions directly, but more people's dispositions toward positive emotions. mDES measures 20 discrete emotions, including positive emotions amusement, awe, contentment, gratitude, hope, love, pride, sexual desire, joy, interest, surprise and eight negative emotions. mDES can be used as a reliable tool for the assessment of positive ($\alpha = .79$) and negative ($\alpha = .69$) emotions for a specific time frame, e.g., the past 24 hours. Thus, mDES is a retrospective, rather than present acute state, method.

Awe is a specific self-transcendent positive emotion, and it is only relatively recently that researchers have attempted to create scales to capture awe. There are five awe questionnaires: The Nature of Awe Questionnaire (NAQ) (Shiota et al., 2007), Awe Experience Scale (AWE-S) (Yaden et al., 2018), Situational Awe Scale (SAS) (Krenzer, 2018), Awe and the Small-self (AS) (Piff et al., 2015), and Gratitude/Awe Scale (GrAw-7) (Büssing et al., 2018). Small-self is conceptualized by Piff et al. (2015) as "a relative diminishment of the individual self and its interests vis-a'-vis something perceived to be more vast and powerful than oneself" (p.2). NAQ and AS are the most widely used, mostly because AWE-S, SAS, and GrAw-7 have only been developed recently. NAQ is a reliable measure of the small-self ($\alpha = .82$), but AS does not seem to have any studies mentioning reliability estimates. AS neglects the additional content suggested by treatments of awe conducted outside of psychology (e.g., admiration mixed with wonder and fear; sublime), whereas SAS reflects psychological, philosophical, and religious perspectives. Both SAS and AWE-S claim to be more robust measures of awe compared to NAQ and AS. AWE-S shows strong internal consistency for each of its six factors: altered time perception ($\alpha = .91$), self-diminishment ($\alpha = .89$), connectedness ($\alpha = .87$), vastness ($\alpha = .85$), physical sensations ($\alpha = .81$), and need for accommodation ($\alpha = .80$) (Yaden et al., 2018). AWE-S also demonstrated strong reliability ($\alpha = .93$). A paper on validating the SAS showed good convergent validity compared to DPES-awe (Shiota et al., 2006) and AS (Piff et al., 2015); additionally there was adequate construct validity among the four factors: connection ($\alpha = .84$), oppression ($\alpha = .83$), chills ($\alpha = .81$), and diminished self ($\alpha = .69$) (Krenzer, 2018). The authors of SAS point out that while SAS and AWE-S share a similar factor structure, it differs in that AWE-S includes additional factors that did not emerge in SAS (i.e., perceived vastness and need for accommodation) and SAS includes a negatively valenced sub-scale of awe that may capture a broader range of contexts. GrAw-7 is an extended version of the 3-item Gratitude/Awe subscale of the Spiritual Practices (SpREUK-P) scale. It is intended to measure dispositional gratitude/awe as a trait, namely feelings of gratitude, reverence/awe, and experiencing the beauty in life. GrAw-7 is strongly correlated with the perception of the

sacred in life (Daily Spiritual Experience Scale) in religious persons, but it can also be used in secular populations. One validation study showed it had good internal consistency (α = .82) (Büssing et al., 2018); however, no other study has confirmed this.

1.5.1.4 Peak and Mystical Experience Questionnaires

Mystical experience, as conceptualized by Stace (1960) and summarized by Robertson (1962), is "the intuition of oneness with the ultimate spiritual reality" (p.180). Some of the earliest research on self-transcendence aimed to objectively measure peak and mystical experiences in the context of peak performance, sport, religion and spirituality, hallucinogenic experiences. These scales are still relevant and used today. Two scales look at peak experiences: Peak Scale (PS) (Mathes, 1982) and Experience Questionnaire (EQ) (Privette and Bundrick, 1987). PS measures tendencies for peak experience, and not assessing peak experience themselves, whereas EQ explores the phenomenon of peak experience. Both PS ($\alpha = .94$) and EQ ($\alpha = .70$) have adequate reliability.

There are five scales that attempt to measure mystical experience: Mysticism Scale (MS) (Hood, 1975), Daily Spiritual Experience Scale (DSES) (Underwood and Teresi, 2002), Spiritual Transcendence Scale (Spirit-TS) (Piedmont, 1999), Mystical Experience Questionnaire (MEQ) (MacLean et al., 2012), and States of Consciousness Questionnaire (SOCQ) (Griffiths et al., 2006). Spirit-TS assesses mysticism as a personality trait with adequate reliability ($\alpha = 0.86$). Spirit-TS generalizes to a wide range of faith traditions. MS and DSES both are used within the context of religious and spiritual experience, and report sufficient construct validity and internal consistency ($\alpha = .93$). However, they may miss different noetic qualities of mystical experience because of their focus. SOCQ is similar to MS, expect more for hallucinogenic experiences. MEQ also assesses hallucinogenic effects but in laboratory settings. SOCQ contains 43 items from the MEQ, but adds distractor items to ensure whether a participant had a "complete" mystical experience or not. Both scales have shown good internal validity and reliability.

1.5.1.5 Altered States of Consciousness and Transcendence Questionnaires

The questionnaires we have described so far have focused on specific constructs of self-transcendence. Here, we describe and discuss questionnaires that attempt to look at altered states of consciousness and transcendence generally. Three scales assess the occurrence of the phenomena on different consciousness dimensions: Phenomenology of Consciousness Inventory (PCI) (Pekala and Levine, 1982), Altered States of Consciousness Rating Scale (OAV) (Bodmer et al., 1994; Studerus et al., 2010), 5-Dimension Altered States of Consciousness (5D-ASC) (Dittrich, 1998; Dittrich et al., 2010), and 11-Dimension Altered States of Consciousness (11D-ASC) (Studerus et al., 2010). All of these scales are very lengthy (53 to

94 items) and have acceptable levels of reliability. They have been used mostly with understanding experiences from taking hallucinogens such as psilocybin. The consciousness dimensions themselves are different across these scales. 11D-ASC has better discriminant and convergent validity scores compared to 5D-ASC, but has lower reliability. The original OAV is shorter than the 5D-ASC with comparable reliability. The new OAV may provide a better fit, and lower order scales do have sufficient validity and reliability (42-items).

Two scales measure self-transcendence as nondual awareness: Nondual Awareness Dimensional Assessment-Trait (NADA-T) and Nondual Awareness Dimensional Assessment-State (NADA-S) (Hanley et al., 2018). Both NADA-T and NADA-S are 13 items long with good reliability ($r = .93$). While they have not been used widely in assessing self-transcendence since they are relatively new scales, they promise to capture aspects of self-transcendence that other measures do not. For example, TMS captures the decentering aspect of self-transcendence, while NADA measures the form and formless absorption (i.e., relational self-transcendence) and experiential emptiness of self (i.e., annihilational self-transcendence) (Hanley et al., 2018). Another consciousness related measure of self-transcendence is Ego-Dissolution Inventory (EDI)(Nour et al., 2016). EDI is 16 items that assess the associated feeling of increased union with one's surroundings through two constructs: ego-dissolution and ego-inflation. It has sufficient construct validity ($\rho = .735$), and is primarily used in measuring ego-dissolution in psychedelic experiences.

Other scales look at self-transcendence through different lenses: Self-transcendence Scale (STS) (Reed et al., 1989), Temperament and Character Inventory (TCI) (Cloninger et al., 1993), Adult Self-Transcendence Inventory (ASTI) (Levenson et al., 2005), the Self Expansiveness Level Form (SELF) (Friedman, 1983), and the Portrait Values Questionnaire Revised-RR-Self-transcendence Subscale (PVQ-RR-ST) (Schwartz, 2012). STS, TCI, SELF, and PVQ-RR-ST measure self-transcendence as a trait, and not a state. STS is used widely in nursing studies and has been adapted for use with adolescent, adult, and older adult populations. Reliability ranges from $.80 - .88$, with test–retest reliability of .95. SELF is designed to assess self-expansiveness, which has been operationalized as three distinct levels based on a spatial-temporal cartography of self-concept: personal, middle, and transpersonal. A validation study found SELF to have good internal consistency ($\alpha = .66 - .81$) and test-retest reliability (r =.8-.83) (MacDonald et al., 1994). TCI has gone through several iterations. The original has 226 items with True/False answers and the revised TCI has 240 items using a 5-point Likert scale. Self-transcendence is a sub scale with 33 True/False items (TCI) or 26 5-point Likert scale items (TCI-R). SELF and STS are significantly shorter (15 items) but may not capture the subtle nuances of qualitative experience. TCI is comprehensive, but is not inclusive of religious and spiritual components of self-transcendence. ASTI measures transcendence as a developmental process that is more lifespan inclusive, and is used in studies assessing wisdom since self-transcendence is considered a high level of psychological development. Its reliability is satisfactory ($\alpha = .83$), and moderate internal

consistency of .66. PVQ-RR-ST is a sub-scale of the PVQ. PVQ is an alternative to the Schwartz Value Survey (SVS) that measures the ten basic values of persons not educated in Western schools that emphasize abstract, context-free thinking. It can be used with children as well as adult populations, and has good internal consistency ($\alpha = .76 - .85$). Overall, the state scales seem to capture more the experience of self-transcendence, but have not been generalized across different experiences of self-transcendence. The trait and developmental scales of self-transcendence are good for assessing people's tendencies for self-transcendence, but may not be suitable for short-term measures.

1.5.2 Diary and Journal Entry

Diary studies, in general, are a research method for collecting information on participants' lives. Specifically, researchers are usually most interested in the behaviours, thoughts, and feelings of participants over time. Diary methods have been around for a long time, but modern diary methods are systematic and often highly structured. I will review three different diary methods: Narrative Recall, Diary Entries, and Experience Sampling.

Narrative Recall for studying emotion is when participants would recall and write about a personal experience involving the theoretically defined, prototypical elicitor of each emotion. Narrative Recall has been used in emotion research for decades as a well-validated measure (Shaver et al., 1987), however Griskevicius et al. (2010) further developed the method by recognizing that using the emotion word as a prompt was biasing participants and decreasing validity. With Griskevicius et al. (2010)'s method, participants are not asked to write about an "emotion word" so that the definition is not constrained by researchers; participants can give rich descriptions of positive emotions. Narrative recall has been used to capture both the state and trait experience of awe (Piff et al., 2015; Shiota et al., 2007; Yang et al., 2018; Zhao et al., 2018), and has been used in classifying emotions generally including self-transcendent emotions of love, compassion, amazement, wonderment, awe, and elation (Shaver et al., 1987). However, this method is very time consuming to both conduct and analyze. Diary Entries are long-term written accounts that are suitable for studying the long-term effect of an event, when the event cannot be studied in a laboratory, and when researchers want to know how participants reflect about an experience through time (Bolger et al., 2003). This method can give researchers new insight into a phenomenon and participants can give rich, thick descriptions. For example, researchers have used diary entries to study mindfulness, dreams, and mystical experiences (Cangas et al., 2008; Hall and Van de Castle, 1966; Sokel, 1978; Zhu et al., 2017). However, these accounts can be distorted, very selective and not representative of the whole experience (Janssens et al., 2018). For salient activities, they are less subject to retrospective bias than are interview data. Experience Sampling was one of the first psychology methods for studying emotions (Csikszentmihalyi et al., 1977) as a way to provide a valid instrument to describe variations in self-reports of mental processes. Participants report (e.g., write notes or type in an app)

what they were experiencing just before the prompt of a pager or similar signaling device. The signals are typically given at random times to minimize instrumentation effects based on the expectation of a page at a particular time. The experience sampling method has been used in studying flow in different contexts: self-expansion in couples (Graham, 2008), experience at work (Fullagar and Kelloway, 2009), peak experience in the Grand Canyon (Panter, 2017), during sport (Jackson, 2000), and in virtual reality (Gaggioli, 2012). This method has also been used in studying different forms of focused attention or mindfulness (Abuhamdeh and Csikszentmihalyi, 2012; Easterlin and Cardeña, 1998; Smallwood et al., 2012). Experience Sampling reports acceptable levels of internal consistency and test-retest reliability, but researchers recommend using other measures to corroborate the results and ensure validity (Csikszentmihalyi and Larson, 2014).

1.5.3 Interviews

Contemporary research on consciousness started with functionalist psychologists, phenomenology in philosophy, and the Gestalt approach. However, the popularity of behaviourism eclipsed this research until the 1960s with increased interest of altered states of consciousness (Cardeña and Pekala, 2014). Many scientists dismissed introspective methods claiming they were unreliable, biased, and un-objective. Others conceded that no science is observer-free because we always view science from a certain sociocultural and psychological perspective. Different interviewing methods of assessing introspective experience, such as self-transcendence, can be phenomenological, concurrent, or retrospective.

1.5.3.1 Phenomenological Interviews

The interpretive framework in phenomenology is essentially postmodern: human experience is complex, experienced subjectively, and has meaning. Many articles on phenomenology research are focused on how the data are analyzed rather than how its obtained (Moustakas, 1994). Giorgi (1985), a phenomenology researcher, stated that questions should be broad and open ended so the participant can express their view point extensively and limit interviewer bias. However, he failed to describe how to proceed in the interview after stating those initial generalist questions. Bevan (2014) describes a three-part guide to phenomenological interviewing to help better consistency and address criticism of approach being too open ended and biased: contextualization, apprehending the phenomenon, and clarification. Phenomenological interviewing can provide thick, rich descriptions where the essence of experience or phenomenon emerges from participants rather than existing theory or research. Moreover, it does not impose existing theoretical models and is very comprehensive. However, it may be too structured for some researchers, an understanding of assumptions is required, philosophical ideas are abstract, participants need to be carefully chosen, finding participants may be difficult if the phenomena is very specific and rare, bracketing personal experiences is needed, and it is very time consuming. Phenomenological methods have been

used to measure constructs related to self-transcendence such as lucid dreaming (Kitson et al., 2018), peak experiences (Panzarella, 1980), wonder (Gallagher et al., 2015), altered states of consciousness in float tanks (Kjellgren et al., 2004), meditation (Downey and Cohen, 2018); but also has been used to measure self-transcendence itself in women with breast cancer (Coward, 1991, 1990), gay men and women with AIDS (Coward and Lewis, 1993; Coward, 1995), and in healthy populations (Coward, 1996). Microphenomenology is a method for exploring lived experience very finely or for a singular event (Petitmengin, 2006), with a much more narrow view than phenomenology. This method is also comprehensive, with a rigorous technique, high level of reliability, and fine degree of granularity. However, the interviewer needs to be highly trained in the interviewing technique to ensure reliability. Microphenomenology has been used to study awe (Quesnel et al., 2018; Stepanova et al., 2019), meditative experiences (Petitmengin et al., 2017; Prpa et al., 2018; Przyrembel and Singer, 2018), and altered states of consciousness caused by DMT–a fast-acting tryptamine psychedelic (Timmermann et al., 2019). Both phenomenology and microphenomenology can be useful in describing self-transcendence, but which one you use depends on if you want to study the experience generally and across life times (phenomenology), or if you want to look at one specific experience in great detail (microphenomenology).

1.5.3.2 Concurrent Interviews

Concurrent methods have the advantage of gathering rich data while the experience is happening, which significantly reduces memory bias that comes from retrospective reports. The drawbacks include being not easily quantifiable, it may not be a comprehensive account, there is a chance of reactivity during the process, and some experiences may not translate well because of temporal and representational limitations of language and translation between thought and experience. However, these methods seem to have good concurrent validity. Thinking Out Loud (Ericsson and Simon, 1980; Watson, 2009) is one method where participants verbally report what they are experiencing while they are experiencing it. This method can be helpful for real-time experiential reports, but can be intrusive or disruptive of the experience while it happens. Researchers have used the Thinking Out Loud method to understand experiences of mindfulness (Aslan et al., 2016), transformative experience in the context of diabetes (Paterson et al., 1999), and altered states of consciousness (Marcusson-Clavertz and Cardeña, 2011). Cued-recall Debrief (Omodei and McLennan, 1994), in contrast, allows the participant to first have the experience while they are recorded from the firsperson perspective, and then are asked to verbally report their thoughts and feelings while watching the replay. The major advantage of this is not disrupting the experience itself; this is especially important for a transcendent experience where disrupting the participant to ask questions would most likely negatively impact the experience. These methods have been used in several Human-Computer Interaction (HCI) and Psychology studies of emotion (see Supplementary Material for details). For example, the cued-recall debrief method has

been used to assess real-time emotions (Bruun and Ahm, 2015; Bruun et al., 2016), affective responses (Bentley et al., 2005), and decision making(Omodei and McLennan, 1994). While this method seems promising in assessing states of self-transcendence in real-time, only a few studies have actually managed to implement this measure for self-transcendence specifically (Quesnel et al., 2018; Stepanova et al., 2019).

1.5.3.3 Retrospective Interviews

Retrospective interviews are used when interviewing the participant during the experience is not possible or impractical. Often this is done with self-transcendent experiences that have already happened to the participant. The most common type of retrospective interview for self-transcendence is the semi-structured interview (Brinkmann, 2015). The goal is to capture rich, detailed nuanced answers that uncover subjective differences and specificities of the interviewee. Participants verbally respond to questions that were created beforehand. Normally all of the questions are asked, and similar wording is used from interviewee to interviewee. However, sometimes questions may not always follow the exact order. While this allows more freedom to explore self-transcendence, which may also provide new insight, this method is time consuming and the quality of data largely depends on the interviewer's skills. Rather than open interviewing, which has virtually no structure, semi-structured interviews are pertinent when the researcher is beginning the investigation with a fairly clear focus rather than a general focus, so that they can address more specific issues. Structured interviews might be too restrictive for exploring a phenomenon like self-transcendence. Another form of retrospective interviewing is Retrospective Reports; Maslow (1959) provided a guide to investigating peak experiences where participants are asked to describe the most wonderful or joyful experience of their lives, how they felt, and if and how it affected their lives through in-depth interviews or open-ended surveys (15-30 minutes). Similar to semi-structured interviews, there are usually only a few pre-determined questions. However, retrospective reports include a coding scheme and member checking in the process to improve reliability and validity. Both semi-structured interviews and retrospective reports can provide rich detail and a comprehensive view on self-transcendence. However, both suffer from similar drawbacks of memory bias.

1.5.4 Neurological and Physiological Measures

There are a variety of physiological measures that tap into self-transcendent experiences. Many studies involve meditation, which is related to self-transcendence, but not much research is on self-transcendence in particular. There is a challenge with physiological measures mapping to specific states and emotions because our bodies are complex and the same physiological response (e.g., increased heart rate) may serve multiple functions and correlate with different states depending on other factors. That said, we can still use physiological mea-

sures as yet another lens into understanding self-transcendence. We will discuss two types of measures: neurological and non-neurological (which we will simply call physiological).

1.5.4.1 Neurological Measures

Neurological changes in the brain can be observed through several techniques, each with advantages and disadvantages. There are two types of neurological techniques: direct and indirect measures. Direct measures look at neural activity of the brain itself, while indirect measures look at other bodily changes that are related to direct brain activity. Direct measures include brain lesions, Electroencephalography (EEG), and Magnetoencephalograph (MEG). Indirect measures are Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT), Magnetic Resonance Imaging (MRI), Functional Magnetic Imaging (fMRI), and Functional Near-Infrared Spectroscopy (fNIRS).

Brain lesions are one of the oldest neurological methods for investigating the link between brain function and behaviour (Broca, 1861). Participants have portions of their brain removed and a comparison is made between performance before and after the lesion and consequent deficits are noted. One can also study participants whose brains have been damaged through natural means. Typically, this method is now only used when participants need surgery on that particular part of the brain, since it would be unethical to run a true experiment. While this method shows us insight into the causally necessary function of brain structures, it is extremely invasive, often not generalizable, and assumes that discrete anatomical modules deal with different cognitive functions. Studies have shown lesions to the parietal lobe increase the propensity for self-transcendence (Urgesi et al., 2010). Another direct measure of brain function is EEG, which directly measures brain electrical activity just under the scalp via electrodes placed on the skin (Berger, 1929). This method is widely used to study experiences such as meditation and hallucinogens because it is noninvasive, portable, relatively low-cost, and provides good temporal resolution. Different meditation types may correspond with different brain waves: focused attention (beta 13-30Hz; gamma 30-50Hz), open monitoring (theta 4-8Hz), and automatic self-transcending (alpha-1 8-10Hz) (Cahn et al., 2012); although neuroelectric correlates of meditation have not yet been firmly established and should be considered with caution (Fox and Cahn, 2018). This method is good for recording real-time measures of brain activity, and several consumer EEG products make it accessible to researchers. However, there are several drawbacks to EEG. First, electric conductivity may vary widely from person to person and also over time, due to the natural conductivities of other tissues such as brain matter, blood, and bones. Because of this, it is sometimes unclear exactly which region of the brain is emitting a signal. Also, it can be difficult to determine the source of the underlying signal since EEG only records signals directly below the scalp. It also requires a reference electrode, which may not always be

reliable. EEG has been used to measure meditation-induced altered states of consciousness (Aftanas and Golocheikine, 2002; Lehmann et al., 2001), mystical experience (Tenke et al., 2017), and near death experience during meditation (Beauregard et al., 2009). EEG has also been used to measure related constructs of self-transcendence including brain states during transcendental meditation (Banquet, 1973; Yamamoto et al., 2006), yogic meditation and trance (Das and Gastaut, 1955), and mindfulness meditation (Kerr et al., 2013; Travis and Arenander, 2004). The popularization of mindfulness meditation in Western culture and the development of consumer EEGs has stemmed several meditation-related digital experiences and apps that claim to measure mindfulness (Amores et al., 2016; Antle et al., 2018; Choo and May, 2014; Gervais et al., 2016; Gu and Frasson, 2017; Hinterberger, 2011; Kosunen et al., 2016; Prpa et al., 2015). A more recent technique that is similar to EEG is MEG, which maps brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain, using very sensitive magnetometers (Cohen, 1968). Here, participants may be positioned on a movable examination table or seated in a comfortable chair within a room that shields out any electric and magnetic noise that could interfere with the exam. They will be positioned within the stationary helmet that contains the MEG detectors placed on the head. MEG has been used to measure brain activity during transcendental meditation (Yamamoto et al., 2006), mindfulness meditation (Kerr et al., 2013; Wong et al., 2015), and mindfulness-induced selflessness (Dor-Ziderman et al., 2013) and altered states of consciousness (Berkovich-Ohana et al., 2013a). Compared to EEG, MEG has improved spatial resolution because magnetic fields are less distorted by bone (skull). Moreover, activity is localized with more accuracy compared to EEG and is reference free. However, MEG is not as good as fMRI at localizing activity. Some other drawbacks are that MEG needs specialized shielding to eliminate the magnetic interference, it requires highly sensitive instrumentation, and it is not portable. Both MEG and EEG meet high standards of reliability and validity.

In terms of indirect measures of brain function, PET illustrates where neural firing is taking place by injecting a small amount of radioactive tracer and taking a picture of the cerebral blood flow (Phelps et al., 1975). This method is important for understanding the role of various neurotransmitters in cognition, such as glutamate and GABA (Newberg et al., 2001). PET's advantages include little artifacts in the scan, high spatial resolution, and quick scan times (30sec). The disadvantages are that we can only locate generalized areas of brain activity and not specific locations, it is expensive, invasive, and not suitable for children or vulnerable populations because of the radioactive elements. PET has been used to measure meditation-induced altered states of consciousness (Herzog et al., 1990; Kjaer et al., 2002; Lou et al., 1999), spiritual experiences (Borg et al., 2003), mindful awareness (Hakamata et al., 2013; Karlsson et al., 2011), and psilocybin-induced altered states of consciousness (Gouzoulis-Mayfrank et al., 1999; Vollenweider et al., 1997). Similar to PET is SPECT, which uses a radioactive compound and gamma camera to render a 3D map of

a person's body (including brain) (Kuhl and Edwards, 1963). While SPECT is relatively inexpensive compared to PET, it does have longer imaging times and has a high rate of false positives. SPECT can be used to complement any gamma imaging study, where a true 3D representation can be helpful, e.g., tumor imaging, infection (leukocyte) imaging, thyroid imaging or bone scan. It can be used to provide information about localized function in internal organs, such as functional cardiac or brain imaging. SPECT has been used to show how meditation-induced peak experience activates the prefrontal cortex (Newberg et al., 2001). It has also been used to measure brain states during religious and mystical states (D'Aquili and Newberg, 1993), hallucinogenic experiences from mescaline (Hermle et al., 1998), and ayahuasca (Riba et al., 2006; Sanches et al., 2016). Another indirect measure of brain functioning is MRI, which measures the change in blood flow related to energy level in brain cells by typically using the blood-oxygen-level dependent (BOLD) contrast, (Lauterbur, 1973). Participants are subjected to a powerful magnet that aligns the hydrogen nuclei of water atoms inside of their brain and can determine changes in the amount of brain tissue (structural MRI) or in the amount of blood flow (functional MRI). Typically, the more active a particular brain structure, the more blood flow it receives. Functional MRI (fMRI) uses the same basic principles as structural MRI, except that the former measures metabolic activity around anatomical structures whereas the latter takes 3D images of the anatomical structures themselves. Like MRI, fMRI has been used to quantify the volume of particular brain structures. fMRI can be used to produce activation maps showing which parts of the brain are involved in a particular mental process, whereas MRI only shows the structures. This means that MRI can be used to measure changes in volume or make comparisons between different subjects, e.g., meditation (reviews: (Afonso et al., 2020; Gotink et al., 2016)). fMRI has many advantages: non-invasive; poses little health risk; usable for all ages, including in-utero; wide spread availability; relatively low cost per scan; good spatial resolution; and better temporal resolution than other indirect neuroimaging methods, although not as good as EEG. The disadvantages are that fMRI machines are expensive, not portable, very noisy, and cannot be used to evaluate neurotransmitter systems. The noise aspect is particularly troublesome for studying self-transcendence because it can be difficult to get into this state when a giant, loud machine is distracting the participant. A study with transcendental meditators showed that the noise from fMRI strongly influenced both subjective and neurophysiological responses during meditation practice, calling into question the fMRI results (Travis et al., 2020). There is no agreed-upon average value for fMRI reliability. There are so many factors spread out across so many levels of influence that it is almost impossible to summarize the reliability of fMRI with a single value. fMRI is one of the more widely used methods of brain imaging for self-transcendence and its constructs. Researchers have used fMRI to capture brain regions that are active during meditation (Lazar et al., 2000; Wang et al., 2011), spiritual experiences (Miller et al.), near death experiences (Beauregard et al., 2009), admiration and compassion (Immordino-Yang et al.,

2009), awe experiences (van Elk et al., 2019), and drug-induced altered states of consciousness with DMT (Daumann et al., 2010), psilocybin (Carhart-Harris et al., 2018; Lebedev et al., 2015), LSD (Carhart-Harris et al., 2016; Tagliazucchi et al., 2016), and ayahuasca (de Araujo et al., 2012; Palhano-Fontes et al., 2015). fNIRS is a non-invasive and safe optical technique that uses light emitting diodes or laser diodes to measure human cerebral cortex oxygenation changes in response to certain stimuli/tasks. Compared to fMRI, fNIRS is silent and tolerable to movement artifacts, it measures oxygenated hemoglobin (O_2Hb) as well as deoxygenated hemoglobin (HHb), it allows long-time continuous measurements as well as repeated measures in a short time span, and it has a higher temporal resolution. Some of fNIRS's limitations are that it has poor spatial resolution, little standardization, and can have unstable accuracy between sessions. Overall, fNIRS is good for when you want a small, wearable device that is movement robust, especially for neuromonitoring and neurorehabilitation. In the context of self-transcendence, fNIRS has been used to measure positive emotions such as awe, gratitude, and love (Hu et al., 2019), brain states during mindfulness meditation (Gundel et al., 2018), sustained attention meditation (Zheng et al., 2019), and drug-induced altered states of consciousness with psilocybin (Scholkmann et al., 2019).

1.5.4.2 Physiological Measures

There are many techniques for measuring physiological processes related to self-transcendence. Psychophysiological measures use indices of bodily responses that reflect variation in psychological states (Potter and Bolls, 2012). Unlike direct measures of the brain, psychophysiological correlations are not causal, but are instruments in which to test theories. Psychophysiological techniques use specific tools for measuring the physiological response: GooseCam for philoerection (goosebumps) (Benedek et al., 2010); Pneumograph for respiration (Marey, 1878); Electrodemograph (EDG) for skin electrical activity (Vigouroux, 1879); Photoplethysmograph (PPG) for blood flow changes (Hertzman, 1937); Electrocardiograph (ECG/EKG) for heart rate and heart rate variability (HRV) (Einthoven, 1895); Electromyograph (EMG) for muscle electrical activity (Hardyck et al., 1966). Each of these psychophysiological instruments allows measuring specific characteristics of self-transcendence that would otherwise not be captured in self-reports (Bartholow and Bolls, 2013). For example, a study of awe showed a mixed valence by means of sEMG and a unique physiological pattern resembling a freezing or dissociation-like response (Chirico et al., 2017).

GooseCam investigates goosebumps as a response to strong emotional experiences by using a high-quality camera to record the surface of the skin. Goosebumps have been linked to constructs of self-transcendence such as peak experiences and awe (Grewe et al., 2009). Several research groups have used goosecam to measure instances of awe, e.g., (Benedek et al., 2010; Quesnel and Riecke, 2018; Sumpf et al., 2015; Wassiliwizky et al., 2017). This

method is shown to be robust to variations in skin characteristics, but there is reduced internal validity because this method does not distinguish between the subjective sensation of chills and the objective phenomenon of visible piloerection. Pneumograph is one of the earliest physiological measures that records velocity and force of chest movements during respiration. Participants wear one or more straps around their chest and abdomen, which measures the expansion and contraction (i.e., volume) of their breathing. Respiration rate has been shown to correlate with level of mindfulness, i.e., slower breathing indicates higher degree of mindfulness (Ahani et al., 2014; Wielgosz et al., 2016), while showing mixed response to peak experiences and self-transcendent emotions, i.e., indicating both physiological arousal and physiological calming effects (Clayton et al., 2019; Mori and Iwanaga, 2017). While this is a relatively easy method to use, movement artifacts can influence the results. EDG measures skin electrical activity directly (skin conductance and skin potential) and indirectly (skin resistance) using electrodes placed over the digits or hand and wrist. As sweat increases in the ducts, the resistance at the skin goes down, resulting in higher levels of recorded skin conductance. Skin conductance is a reliable measure of emotional arousal that reflects the level of activation within the emotional and motivational systems. Skin conductance has been used as a measure of awe (Chirico et al., 2017; Grewe et al., 2009), peak experiences (Mori and Iwanaga, 2017), self-transcendent positive emotions (Shiota et al., 2011), and self-transcendence generally (Clayton et al., 2019). One thing to keep in mind when using EDG is that it only measures emotional arousal, not valence. PPG measures the relative blood flow through a digit sensor attached by a Velcro band to the fingers or to the temple to monitor the temporal artery. PPG signal is strong and robust, but a huge range in individual differences and indirect measures of self-transcendence makes reliability challenging. A more direct measure of heart activity is ECG/EKG, which measures the electrical activity of the heart by using electrodes placed on the skin. ECG is more accurate than PPG in measuring HRV, however wearing electrodes on the torso, wrists, or legs can feel more invasive, especially if the participant has lots of hair. Heart activity in general is innervated by both the central and peripheral nervous system, so it can be difficult to determine the nature of the feeling, i.e., whether it is positive or negative. Another drawback of using HRV is that one must account for baselines and individual differences. HR and HRV have been used as measure of self-transcendence (Clayton et al., 2019), awe (Grewe et al., 2009; Sumpf et al., 2015; Wassiliwizky et al., 2017), peak experiences (Mori and Iwanaga, 2017), mindfulness (May et al., 2016), and self-transcendent positive emotions (Shiota et al., 2011). Finally, EMG, i.e., surface EMG, measures the electrical signal associated with muscle activity. In terms of emotion research, this is typically done by placing electrodes on specific facial muscles involved in the valence of emotional processing: corrugator supercilii, orbicularis oculi, and zygomaticus major. Facial EMG is a reliable and valid method for measuring emotional valence (Potter and Bolls, 2012). fEMG has been used to measure self-transcendent emotions (Clayton et al., 2019), awe (Chirico et al., 2017), and flow (Cheron,

2016). EMG can be a useful diagnostic tool, the electrodes are easy and quick to apply with minimal discomfort. Yet, adipose tissue (fat) can affect EMG recordings, compliant skin is needed for accurate readings, and muscle cross talk can occur.

All of these physiological measures can provide an objective view of self-transcendence because it is hard to fake physiological data. That said, the Hawthorne effect can threaten internal validity, i.e., people behave differently when they know that they are being observed. There is also an external validity threat when using a convenience sample, which is not representative enough of the population, because there is a huge variation in individual differences and a large, representative sample is needed to account for them. Correct sensor placement is also critical because wrong placement will result in measuring the incorrect bodily response. Most transcendence related research that uses physiological measures is actually measuring arousal and valence generally, and not a discrete emotion. This is because our bodily reactions are complicated and intertwined. However, there are some researchers trying to measure discrete emotions, such as awe, gratitude, and love (Koelstra et al., 2012; Shiota et al., 2017).

1.5.5 Behavioural Measures

Behavioural measures are overt actions and reactions that are observed and recorded, exclusive of self-reported behavior. Behavioural measures do not suffer the same reliability and validity threats that introspective measures do. However, self-transcendence is generally considered a psychological phenomenon, so studying it from a behaviourist perspective is difficult. Proxy measures look at aspects thought to be related to self-transcendence, such as pro-sociality and empathy, e.g., (Piff et al., 2015; Quesnel et al., 2018; Rosenberg et al., 2013; Saroglou et al., 2008; Van Lange et al., 1997). Other proxy measures include body size estimation (van Elk et al., 2016) and time perception (Rudd et al., 2012), where a smaller size estimation and slower time perception were correlated to self-transcendence. Although, a recent paper found experimentally induced awe does not affect implicit and explicit time perception (van Elk and Rotteveel, 2019). The main method of studying self-transcendence behaviour is observation, where the researcher watches (i.e., observes) behaviour as it organically and spontaneously unfolds in a natural environment. No one really knows when the method of observation for scientific study dates back to. In modern times, it is used in grounded theory and ethnographic approaches (Creswell, 2012). Participants are either aware (overt) or not (covert) they are being studied. Observations can be in a controlled setting, in a natural environment, or the researcher can join in as part of the group. Observational research is used when other data collection procedures, such as surveys, questionnaires, etc. are not effective or adequate. They are also used when the goal is to evaluate an ongoing behaviour process, event, or situation; or when there are physical outcomes that can be readily seen. For example, gestures, interactions, voice qualities, and facial features like eye gaze, pupil dilation and blinking can indicate an affective state (Sharma and Gedeon,

2012). Typically, these behaviours are coded and analyzed across data sources. Observations can explain meaning and context, which is important for self-transcendence. However, they can be viewed as too subjective, the Hawthorne effect can affect validity, and results depend on the researcher's role. Overt observation may affect validity of findings, and covert may be unethical, have a high potential for role conflict, and may not tell the whole story. This method is also very time consuming and, in the case of self-transcendence, should probably be used in conjunction with other methods rather than relying on a single data source. Some researchers have used observation in studying awe (Quesnel et al., 2018), mindfulness (Antle et al., 2018; Gervais et al., 2016; Van Rooij et al., 2016), self-transcendence in women with breast cancer (Coward, 1990), and ego dissolution after taking ayahuasca (Uthaug et al., 2018).

1.6 Discussion

1.6.1 Conceptual Challenges of Self-transcendence Methods

Different Underlying Theories for Different Measures

Generally, there are three views of self-transcendence: physiological (neurobiological mechanisms), phenomenological (experiential), and conceptual (traits, values). Each of these theories offer a different perspective in which to define self-transcendence, which in turn impacts how one measures self-transcendence.

Physiological measures of self-transcendence aim to objectively capture states of self-transcendence. For example, people report having a mystical experience when there is decreased activation in parietal functioning (Azari et al., 2001; Beauregard and Paquette, 2006; Johnstone et al., 2012). That said, even seemingly objective measures are not directly capturing self-transcendence as a whole but are instead measuring correlates or outcomes of self-transcendence, e.g., increased heart rate.

Phenomenological measures of self-transcendence aim to capture the lived experience of self-transcendence as a whole and highly individualized phenomenon, e.g., through ground theory interviews (Garcia-Romeu et al., 2015). Whereas physiological measures are reductionist, phenomenological measures of self-transcendence seek to understand the context in which self-transcendence occurs, the physical sensations, and the perceptual, cognitive and affective experiences.

On the other hand, conceptual measures of self-transcendence consider a wider range of social, developmental, and personality facets of self-transcendence that physiological and phenomenological measures do not capture. Still, conceptual measures should be used with caution since they are each developed from a specific theoretical lens. For example, self-transcendence as a personality trait in Nursing is derived from Neo-Piagetian theories. Moreover, when looking at the mindfulness facet of self-transcendence, these measures are derived from either Buddhist psychology (e.g., FMI) or with a pragmatic approach (e.g., KIMS)

(Sauer et al., 2013). There are other conceptually based measures of self-transcendence that view it as a state, not a personality trait, e.g., TCI (Cloninger et al., 1993).

Unclear Constructs and Facets of Self-transcendence

Koenig (2008) postulates that the term "spirituality" is often conflated with general good mental well-being or health. This is problematic both because the construct should be distinct and because this definition deviates from the original meaning of the word, i.e., religious or secular person living by a set of ethical and moral values and meanings. Self-transcendence can also suffer from this same issue. For example, several measures only consider the positive aspects of self-transcendence and exclude the "dark side", including absorption, suggestibility, and dissociation, which can have psychotic outcomes (MacDonald and Holland, 2002).

The term "self-transcendence" is so broadly defined in the literature that it can encompass a wide range of constructs that each contain multiple facets. For example, mindfulness is considered a construct of self-transcendence (Yaden et al., 2017a), and mindfulness itself has several facets, e.g., FFMQ (Baer et al., 2006). With this broad and widely encompassing definition, it is difficult to derive a measure that is specific to self-transcendence and at the same time encompasses all its aspects.

Direct Measures versus Outcomes and Correlates of Self-transcendence

Self-transcendence in itself can be difficult to capture and measure, especially because recreating the right conditions for a self-transcendence to occur is challenging. Some methods ask the participant to recall a time when they had a self-transcendent experience, e.g., AWE-S (Yaden et al., 2018) or EQ (Privette and Bundrick, 1987), while others try to evoke the experience, e.g., micro-phenomenology (Petitmengin, 2006). In order to avoid having to reproduce self-transcendence or better tap into a previous experience, researchers have looked at proxy measures. For example, self-transcendence is reported to be correlated with self-diminishment (van Elk and Rotteveel, 2019) and pro-social tendencies (Carlo and Randall, 2002). These proxy measures can be powerful tools when direct measures cannot be used or are nor feasible. However, researchers need to be clear on what exactly they measure—self-transcendence or its outcome.

1.6.2 Empirical Support of Self-transcendence Methods

Internal Consistency Reliability

One measure of internal consistency (reliability) is Cronbach's alpha. $\alpha >= .70$ is considered acceptable in most social science research situations. We found that the questionnaires all had sufficient alpha. However, the proxy measures were still lacking measures of internal consistency, with the exception of the Prosocial Tendencies Measure (PTM) (Carlo and Randall, 2002) that showed high internal consistency of $\alpha = .92$. The differences in high and low alpha scores could be the difference in narrow and broad scope. Questionnaires measuring specific constructs of self-transcendence will have higher alpha coefficients than

those measuring self-transcendence more broadly. Additionally, those questionnaires with a higher number of items will have higher alphas. As we can see in Table 1.1, the more broad measures of altered-states of consciousness and self-transcendence, positive emotions, as well as proxy measures have lower alphas than the specific measures of awe, flow, mystical or peak experiences, and mindfulness.

General Measures

Ques.	Item #	α	r
ASC/ST			
PCI	53	.75-.82	.34-.56
OVA	66	.73-.91	.77-.83
5D-ASC	72	.93	.56-.71
11D-ASC	94	.7-.8	–
STS	15	.8-.88	.55-.78
SELF	18	.66-.81	.8-.83
TCI	240 (33)	.9	.52-.82
ASTI	18	.66-.83	–
PVQ-RR-ST	15	.76-.85	–
EDI	16	0.80	.74
NADA-T	13	–	.93
NADA-S	13	–	.94
Positive Emotions			
IOS	7	–	.83
DPES	39	.75-.92	–
mDES	20	.75	–
Proxy Measures			
ZTPI-F	13	.78	.63-.84
Small Self	–	.51	–
PTM	26	.92	.56-.82
Meditation Depth			
MEDEQ	30	.92	.64-.93

Specific Measures

Ques.	Item #	α	r
Awe			
NAQ	16	.82	–
AWE-S	30	.92	–
SAS	18	.84	–
AS	13	.92	–
GrAw-7	7	.82	–
Flow			
FSS	36	.72-.91	.748-.978
DFS-2	36	.81-.9	–
Mystical/Peak Experiences			
PS	70	.92-.94	–
EQ	47	–	.7
MS	32	.93	–
DSES	16	>.9	.85
Spirit-TS	24	.86	–
MEQ	30	.93	.81
SOCQ	100	.71-.95	–
Mindfulness			
MAAS	15	.82	.81
FMI	30	.93-.94	.895
KIMS	39	.76-.91	.65-.86
CAMS-R	12	.74-.8	–
SMQ	16	.89	–
FFMQ	39	.72-.92	.66-.86
SMS	23	.95	.55-.65
TMS	13	.91-.93	.66-.73

Table 1.1: Reliability coefficients of internal consistency measured with Cronbach's alpha and test-retest measured with Pearson's r, and number of items for questionnaires that measure general self-transcendence (left) and specific constructs of self-transcendence (right).

Test-retest Reliability

Test-retest reliability determines the consistency of a test taken multiple times, often denoted as r. Often, $r >= .7$ is the accepted value, but this will depend on the time between test and retest, the length of the test, what is being measured, and the characteristics of the sample. We found that test-retest reliability has been infrequently evaluated in measures of self-transcendence. Approximately half of all the questionnaires tested for test-retest relia-

bility (see Table 1.1). Of those, most questionnaires reported adequate test-retest reliability. Those with low test-retest reliability may be due to the nature of the test; trait measures of self-transcendence will be more stable over time compared to state measures. Test-retest reliability is an important psychometric property for establishing stability of these measures over time. We suggest more validation studies are needed to establish the stability of the construct.

Validity

We considered four types of validity: construct, content, face, and criterion.

The questionnaires of self-transcendence that report adequate validity as the following: PCI, STS, SELF, TCI, ASTI, IOS, PTM, MEDEQ, AWE-S, SAS, DFS-2, EQ, MS, MEQ, SOCQ, MAAS, and TMS. Those that specifically mention construct validity, which can be a measure of overall validity, are PCI, STS, AWE-S, DFS-2, EQ, MS, MEQ, and MAAS.

Diary and journal entry methods overall have good construct validity and they have been used in emotion research for decades as a well-validated measure. Interview measures have good validity when rigorous technique is applied and they can also bring richness to the data that would not otherwise have been captured in a questionnaire or physiological measure. Observations too can have strong validity and bring an in-depth understanding when they are natural.

Neurological measures of self-transcendence vary in accuracy, and not many have been specifically used to measure self-transcendence, but have been used to measure mindfulness meditation and self-transcendent emotions, including decreased self-saliency and increased connection (see Figure 1.3). If considering self-transcendence as an emotional state, then neuroimaging can be limited since there is little evidence that emotions are correlated directly to one specific brain region (Lindquist et al., 2012). As we can see in Figure 1.3, self-transcendence spans multiple brain regions and networks, making it difficult for some neuroimaging techniques with low spatial resolution to accurately measure self-transcendence. For example, EEG and MEG have poor spatial resolution while having a relatively high temporal resolution compared to fMRI. Thus, capturing the specific brain areas of self-transcendence would be more accurate with fMRI. However, capturing self-transcendence in a large noisy machine where the participant is supine also comes with its own challenges.

Physiological measures of self-transcendence are also not straightforward because their indices are often simply emotional arousal and valence; it is difficult to correlate a single physiological response with a complex emotion such as self-transcendence. That said, when combined with other measures that provide ground truth, such as interviews, they can be good indicators that a change has occurred from a normal state of consciousness to an altered one. One research group showed that one can represent subjective experiences of emotion as categorical somatotopic maps (Nummenmaa et al., 2014). While physiological measures can accurately measure arousal, those seeking to find a measure of self-transcendence should use these physiological measures with caution. It is the opinion of some researchers that

there is no physiological "finger print" of any emotion and that our efforts to measure emotions should be directed "to observe, map, and better understand the breadth, nature, and function of this variation in emotion categories" (Siegel et al., 2018, p.36).

1.6.3 Recommendations

Having reviewed the literature on measures of self-transcendence, we have some recommendations on which measure to use to asses self-transcendence. That said, the answer depends on the research context and purpose. Since self-transcendence is broadly defined and contains many constructs, we suggest taking a multi-method approach and triangulating the results for increased validity. One existing methodology that seemed most aligned with capturing the nature of self-transcendence is neurophenomenology—the synthesis of neuroimaging to provide rich empirical data (e.g., EEG, MRI, PET) and valid descriptions of first-person subjective experience (e.g., phenomenology). Neurophenomenology was first introduced by Laughlin Jr et al. (1992), and Varela (1996), and developed by Maturana and Varela (1991); Thompson (2010); Varela (1996). For the phenomenological component, Husserl (1983) developed a method of bracketing knowledge in order to focus on the experience itself and provide an unbiased account. Varela used this interview method to obtain reliable descriptions of first-person experience. Another interpretation of neurophenomenology is the use of micro-phenomenology—a qualitative, second-person interview for the research of first-person accounts of lived experiences. Micro-phenomenology was first introduced by Pierre Vermersch as "entretien d'explicitation" (explication interview) Vermersch (1994) and further developed by Petitmengin (2006); it is now becoming a central element of Varela's neurophenomenology. Taking from neurophenomenology, we suggest two broad approaches of assessing and investigating self-transcendence: (1) in-the-moment and (2) as a value, developmental process, or personality trait.

1.6.3.1 Assessing and Investigating Self-transcendence in the Moment

We propose combining some of the following methods for investigating self-transcendence in-the-moment, which we will elaborate on subsequently:

Questionnaires and Surveys

- Awe Experience Scale (AWE-S);
- Toronto Mindfulness Scale (TMS);
- Nondual Awareness Dimensional Assessment Scale-State (NADA-S);
- Inclusion of Other in Self Scale (IOS);

- Dispositional Positive Emotion Scales (DPES);
- Mysticism Scale (MS)

Observation

- Observation

Interviews

- Micro-phenomenology

Neurological and Physiological Measures

- Electroencephalography (EEG);
- Function Near-Infrared Spectroscopy (fNIRS);
- Electrodemograph (EDG);
- Facial Electromyograph (EMG)

Diary and Journal Entry

- Diary Entry

Questionnaires and Surveys

From the list of questionnaires previously described, we suggest the Awe Experience Scale (AWE-S), Toronto Mindfulness Scale (TMS), Nondual Awareness Dimensional Assessment Scale-State (NADA-S), Inclusion of Other in Self Scale (IOS), Dispositional Positive Emotion Scales (DPES), and Mysticism Scale (MS). To measure state self-transcendence, specifically the decreased self-salience component, we propose using the AWE-S, TMS and NADA-S. There are very few questionnaires that measure state qualities to begin with, and what exist currently are often not well validated. AWE-S, although new, already has some validation studies to support it and likewise for TMS and NADA-S. All of these scales measure a specific aspect related to self-transcendence and may not be all encompassing of the experience, but perhaps with both they will fill in the gaps until we have a better state measure for self-transcendence. Lastly, IOS might be useful in measuring the connectedness aspect of self-transcendence. This measure is unique in that it uses pictures instead of language, which might be useful for capturing the ineffable aspects of self-transcendence. IOS, TMS, and AWE-S are good for assessing "at the present moment", so it might be useful to do pre- and post-measures of these three scales to see if there is a change. Although DPES and MS are not explicitly measuring self-transcendence in the moment, past life experience can play a huge role in both if self-transcendence occurs and how it is experienced. DPES

can provide an assessment of participants' pre-disposition to self-transcendence and MS can provide a brief history of past self-transcendent experiences. With these two measures, one might better control for individual differences. Both of these questionnaires have good reliability and validity, and are widely used. Other questionnaires that assess pre-disposition or traits are not as inclusive for all types of self-transcendence, are not well validated, or are very long and redundant.

Observation

Although psychometric tests can be helpful in understanding complex inner states such as self-transcendence, they often fail to capture the rich, qualitative experiential aspects. Observation methods are useful in filling this gap to see what people experienced both leading up to and during a self-transcendent experience. We suggest a setting where the participant has consented to be recorded but the researcher is not present so the participant can experience self-transcendence without the Hawthorne effect and at the same time researchers can more ethically collect their data. An example might be in a natural environment such as a meditation retreat. A lab could suffice and bring more control to the study, but we recommend creating a welcome and warm space rather than the usual cold and sterile conditions of a lab since mindset and setting are important.

Interviews

Since there are so many facets to explore with self-transcendence, a rich qualitative description would nicely complement the quantitative questionnaires and provide detail and context to the observations. We suggest using the micro-phenomenology method in conjunction with neurological and physiological measures we will describe in the next section. Micro-phenomenology seems to be a good fit for studying self-transcendence in this case because it allows the participant to fully experience self-transcendence without disturbing them with think-aloud methods. It also attempts to avoid memory bias by situating the participant back in the experience they just had through evocation. In contrast, a phenomenological interview seems more fitting to describe multiple experiences over time, whereas micro-phenomenology is about one specific event. Researchers still need to be cautious when using this method since the definition of self-transcendence is still quite broad. That is, there is a risk of missing a critical component while looking too deeply at one component of self-transcendence. Other retrospective interviewing methods seem more flawed and prone to memory bias compared to micro-phenomenology. Cued-recall debrief tries to address the issue of memory bias by showing a first-person recording of the experience during the interview, yet does not have the evocation element that makes micro-phenomenology potentially more valid.

Neurological and Physiological Measures

We would recommend to select some, or if feasible all, of the following neurological and physiological measures in conjunction with micro-phenomenology: EEG, fNIRS, EDG, and facial EMG. Most neurological measures are indirectly measuring something or are very

expensive and not accessible, e.g., fMRI and MEG. Of all the neurological measures, EEG and fNIRS seem to be the best methods in this case because they are non-invasive, relatively inexpensive, portable, and are complementary measures of brain activity. EEG is already extensively used in studying related experiences such as meditation, so it seems like a natural extension to study self-transcendence. However, because of EEG's limited spatial resolution, it would be better to use fNIRS, which has a higher spatial resolution, in conjunction with EEG to achieve a more accurate measure of brain activity. In order to corroborate these measure of brain activity, we suggest using both EDG and facial EMG to measure emotional arousal and valence, respectfully. Both are required to get an accurate representation of the participant's affective state. Other physiological measures could be used to further corroborative the results. Still, it is preferable to not have to subject participants to too many electrodes as this can be uncomfortable, unnecessary, and maybe not all that more helpful.

Diary and Journal Entry

The last measure we would consider for investigating self-transcendence is diary entry. Self-transcendence can be a powerful and profound experience, but the real benefits continue well after the initial experience. With self-transcendence, one hopes to have a general sense of increased well-being, pro-sociality, and positive social values. Therefore, having participants complete diary entries would show how they reflect about the experience through time and show if and how a self-transcendent experience made a lasting and significant impact on their lives.

1.6.3.2 Assessing and Investigating Self-transcendence as a Value, Developmental Process, or Personality Trait

In this section, we suggest methods that are appropriate for measuring self-transcendence as a value, developmental process, or personality trait. We propose the following methods for investigating self-transcendence in their respective contexts based the their validity, reliability, suitability, and weighing the advantages and disadvantages:

Value

- Portrait Values Questionnaire Revised-RR-Self-transcendence Subscale (PVQ-RR-ST)
- Semi-structured interviews

Developmental Process

- Self-transcendence Scale (STS)
- Adult Self-Transcendence Inventory (ASTI)

- Diary Entries
- Retrospective Interviews

Personality Trait

- Dispositional Positive Emotion Scales (DPES)
- Temperament and Character Inventory (TCI)
- Mindful Attention Awareness Scale (MAAS)
- Dispositional Flow Scale 2 (DFS-2)
- Gratitude/Awe Scale (GrAw-7)
- Spiritual Transcendence Scale (Spirit-TS)
- Magnetic Resonance Imaging (MRI)
- Computed Tomography (CT)
- Experience Sampling
- Semi-structured Interviews

Value

Values are generally described as stable, broad goals that are important to us in life (Schwartz, 2012). Values express a person's motivations which may or may not be reflected in behavior. Thus, behavioural, observational, or physiological measures would not be suitable for measuring self-transcendence as a value. PVQ-RR-ST appears to be the only questionnaire measuring self-transcendence as a value. Here, values relate to universalism and benevolence, specifically measuring acceptance, appreciation, and understanding of the welfare of others (Schwartz, 2012). Semi-structured interviews can be used to capture rich, detailed nuanced answers that uncover subjective differences and specificities of the interviewee. Other interview methods we reviewed were either focused on self-transcendence as experiential, e.g., phenomenology or retrospective, or were about self-transcendence in-the-present-moment, e.g., microphenomenology, think-aloud -protocol, and cued recall debrief. Diary and journal methods may provide some context to why a participant may value self-transcendence or not.

Developmental Process

Reed (2013)'s theory of self-transcendence aligns with Frankl and Maslow's developmental stages that need to be fulfilled in order to have a sense of purpose in life. Reed's theory has been primarily used in older adult populations where self-transcendence plays an integral role in healing and in dignified acceptance of the end of life. From this theory, Reed

et al. (1989) developed the Self-transcendence Scale (STS) to identify intrapersonal, interpersonal, transpersonal, and temporal experiences characteristic of later life, which reflect expanded boundaries of self. The Adult Self-Transcendence Inventory (ASTI) is another questionnaire to measure transcendence as a developmental process that is more lifespan inclusive (Levenson et al., 2005). Between the two, we recommend the STS because it is more widely used, it has higher internal consistency, and it reports good construct validity; whereas the ASTI has questionable test-retest reliability and construct validity.

We also recommend diary entries in this case because they obtain rich, longitudinal narratives of individuals' lives that can be a window into how self-transcendence develops over time. Retrospective interviews can also help to understand how self-transcendence as a developmental process changes over time.

Personality Trait

Personality traits are defined as descriptions of people in terms of relatively stable patterns of behavior, thoughts, and emotions, and are therefore summaries of an individual's responses and behaviors (McCrae and Costa, 2003). In order to assess self-transcendence as a personality trait, one should consider the following questionnaires that measure an individual's behavioural, cognitive, and emotional tendencies. The following all have good reliability and encompass both the broad and specific construct of self-transcendence, depending on what you are most interested in. Moreover, we found these questionnaires tended to span across different populations and faiths. That said, if one is interested in a specific context of self-transcendence, e.g., in the Christian faith or involving hallucinogenics, then it would be worth considering measures specifically with those in mind.

For general measures of self-transcendence as a trait, we recommend the Dispositional Positive Emotion Scales (DPES) that assess seven different positive emotions: joy, contentment, pride, love, compassion, amusement, and awe (Shiota et al., 2006). The second measure is Temperament and Character Inventory (TCI) (Cloninger et al., 1993). In terms of measuring specific constructs of self-transcendence, the Mindful Attention Awareness Scale (MAAS) measures general tendency to be attentive to and aware of present moment experience in daily life (Brown and Ryan, 2003). Second, the Dispositional Flow Scale-2 (DFS-2) measures the frequency of flow experiences in chosen physical activity in general (Jackson and Eklund, 2002). Third, Gratitude/Awe Scale (GrAw-7) measures feelings of gratitude, reverence/awe, and experiencing the beauty in life (Büssing et al., 2018). Lastly, Spiritual Transcendence Scale (Spirit-TS) captures a personal tendency to turn towards a larger, objective perspective of reality than one's personal life (Piedmont, 1999).

When considering self-transcendence as a trait, rather than a state, the type of brain imaging used should reflect that goal. Self-transcendence as a state would require measuring brain activity, and thus would need a functional imaging method such as EEG, fMRI, PET, SPECT, or MEG. On the other hand, measuring self-transcendence as a trait can use either a functional imaging method such as EEG or a structural imaging method such as

computerized tomography (CT) or MRI. As Cahn and Polich (2006) point out in their review paper on neuroimaging studies of meditation states and traits, EEG can be used to measure changes in brainwave amplitude in comparisons such as resting vs. meditating or beginner vs. expert meditators. In CT scanning, a computer is used to construct images of the brain (or other parts of the body) from a series of x-ray scans at multiple angles, giving much better resolution than standard x-rays. MRI scans, on the other hand, not only provide higher-definition images than CT scans, but they can also show sagittal and coronal sections of the brain, not just the axial sections to which CT scans are limited. While EEG measures coherence between brain activity or spectral values in different frequency ranges, MRI focuses on activations in different brain areas (Raffone and Srinivasan, 2010). Therefore, it appears the best way to measure self-transcendence as a trait is through a combined method of EEG and MRI, which several studies of meditation have already done (Cahn and Polich, 2006).

Since traits look at patterns of behavior, thoughts, and emotions, experience sampling can help to describe patterns of an individual's daily experience, to evaluate the common experience of situations, and to study the dynamics of emotions and other subjective states. Semi-structured interviews can also help determine patterns; although observation would directly measure behaviour, it would be very time consuming to see stable patterns of behaviour that are warranted for personality traits.

1.6.4 Future Directions

After reviewing the current measures of self-transcendence, we have recommended a multi-method approach with a list of different measures researchers should consider based on their validity, reliability, and suitability. We recommend this multi-method approach since self-transcendence is currently defined in many ways depending on the theoretical lens. As such, we divided our recommendations according to how one conceptualizes self-transcendence, namely as a state, trait, value, or developmental process. We recognize that we have recommended a long list of methods, and due to limited resources many researchers hoping to study self-transcendence may not have the means to use all of the measures we have recommended. In this case, we would still strongly suggest taking a multi-method approach and select the few measures that would be most relevant and accessible to the study. For example, questionnaires are a well validated method of assessing some aspects of self-transcendence, and triangulating that data with a physiological measure and qualitative interviews can increase confidence in the findings. If one were to select only one type of measure, we might suggest taking a qualitative approach since at its core self-transcendence is a subjective phenomena that cannot be reduced to physiological and neurological correlates. Already, there are researchers taking a multi-method approach to measuring self-transcendence or one of its constructs and we might take these studies as examples of how to move forward in the field. Reinerman-Jones et al. (2013) used questionnaires, EEG, ECG, fNIRS, and

phenomenological interviews to investigate awe and wonder in a simulated space travel scenario. Zhu et al. (2017) used a package of probes in the form of photos, diaries, and cards together with questionnaires, ECG, and semi-structured interviews to assess mindfulness.

One of the major challenges in measuring self-transcendence is in capturing it while it is happening. Recent developments in virtual reality (VR) have provided an opportunity to create realistic experiences that can support a self-transcendence. Thus, moving forward, we might use this technology as a way to further explore self-transcendence. Quesnel et al. (2018) used VR to help elicit awe and wonder during a journey through a forest, under water, and space to finally gaze upon the Earth. Quesnel and Riecke (2018) were able to elicit awe in four different Google Earth VR environments. Chirico et al. (2018) found that VR can effectively elicit feelings of awe, and that emotions elicited by virtual and natural conditions were not significantly different (Chirico and Gaggioli, 2019). With the development of VR headsets with integrated physiological and neurological sensors, it seems possible for VR to both help elicit self-transcendence and at the same time measure participant's bodily responses. Moreover, the use of first-person recordings of the virtual scene can be used for cued-recall debrief interviews.

Another challenge we identified in our review is that self-transcendence is measured differently depending on the theoretical lens used to define it. Self-transcendence as an emotional state seems to be the most widely used according to our review. One of the critiques of this view comes from embodied appraisal theory, which states that emotions are perceptions of bodily changes according to somatic theories of emotion (James, 1884). Here, emotions register changes in our bodies, but do not represent bodily changes (Prinz, 2004). Instead of response-dependent properties, emotions represent core relational themes (Lazarus and Lazarus, 1991), i.e., emotions have meaning. According to this theory, we can use physiological signals that correlate with self-transcendence, but self-transcendence, like any emotion, does not represent a change in body physiology. Self-transcendence does represent core relational themes, which inform us about our relationship with the world, embody our convictions, and factor intelligibly into our decisions. Although not everyone would agree with Prinz's embodied appraisal theory of emotions, e.g., Pineda (2015), future research on measuring self-transcendence should carefully consider what measures are actually correlations or proxies of self-transcendence rather than self-transcendence itself. Qualitative experience seems to be the key to measuring and understanding self-transcendence directly.

1.7 Conclusion

Within this paper, we described and reviewed measurement approaches to self-transcendence. Based on our review, we provided recommendations and suitability of methods given different research contexts. We want to reiterate that there is no one answer to the question "how does one measure self-transcendence". The optimal choice needs to be determined by the re-

searcher's objectives and the research questions themselves. We have seen that the construct of self-transcendence itself varies greatly depending on theoretical groundings. Whatever the theoretical framing, we suggest that researchers employ a mixed-methods approach in order to embrace the enactive quality of self-transcendence with empirical rigour.

1.8 Author Contributions

AK, AG, and BR contributed to the initial planning and topic of the review. AC provided guidance on review conceptualization. AK performed the screening and eligibility process, and conducted a qualitative research synthesis of the data. AC provided feedback and additional research synthesis. AK wrote the first draft of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

Chapter 2

Immersive Interactive Technologies for Positive Change: A Scoping Review and Design Considerations

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2.1 Abstract

Practices such as mindfulness, introspection, and self-reflection are known to have positive short and long-term effects on health and well-being. However, in today's modern, fast-paced, technological world tempted by distractions these practices are often hard to access and relate to a broader audience. Consequently, technologies have emerged that mediate personal experiences, which is reflected in the high number of available applications designed to elicit positive changes. These technologies elicit positive changes by bringing users' attention to the self – from technologies that show representation of quantified personal data, to technologies that provide experiences that guide the user closer in understanding the self. However, while many designs available today are either built to support or are informed by these aforementioned practices, the question remains: how can we most effectively employ different design elements and interaction strategies to support positive change? Moreover, what types of input and output modalities contribute to eliciting positive states?

To address these questions, we present here a state of the art scoping review of immersive interactive technologies that serve in a role of a mediator for positive change in users. We performed a literature search using ACM Digital Library, Web of Science, IEEE Xplore, and Design and Applied Arts Index (beginning of literature – January 1, 2018). We retrieved English-language articles for review, and we searched for published and unpublished studies. Risk of bias was assessed with Downs and Black 26-item QAT scale. We

included 34 articles as relevant to the literature, and the analysis of the articles resulted in 38 instances of 33 immersive, interactive experiences relating to positive human functioning. Our contribution is threefold: First we provide a scoping review of immersive interactive technologies for positive change; Second, we propose both a framework for future designs of positive interactive technologies and design consideration informed by the comparative analysis of the designs; Third, we provide design considerations for immersive, interactive technologies to elicit positive states and support positive change.

2.2 Introduction

Technology is becoming increasingly more prevalent in our everyday lives. Yet, for all the new hardware and gadgets available, we have only recently seen an increased interest in designers, developers and researchers deliberately thinking about how these technologies might be used to improve our lives and increase our well-being (Bowman and McMahan, 2007; Gaggioli et al., 2017; Roo et al., 2016; Valmaggia et al., 2016). The Western practice and literature so far has focused primarily on mental health problems and treatments, from a medical or psychiatric lens (Valmaggia et al., 2016) and with a focus on treating symptoms rather prevention. Furthermore, literature focusing on healthy populations and using a preventative medicine point of view is uncommon. Focusing on preventable measures is important because non-communicable diseases cause 70% of deaths globally and about half of all deaths in the US were preventable (who, 2018; Mokdad et al., 2004), and the use of preventative healthcare has shown to provide numerous health benefits and increase quality of life dramatically (Cohen et al., 2008; Maciosek et al., 2010). That said, there does appear to be a rise in interest in using technology for positive human functioning and well-being across many different domains. This diversified interest seems to imply promise for future applications of technology for improving positive experiences and health. Yet, a challenge lies in trying to integrate all the existing knowledge across the various domains because, although they are all aiming toward a common goal, they are using different terminology, frameworks, and theoretical lenses to approach the topic. We have created a visualization in an attempt to better understand both the development of these different domains over time and how they interact with each other (see Figure 2.1), and will elaborate on it below. Approaches to technology that supports positive human functioning and well-being appear to be seeded from three different domains: Psychology, HCI, and Computer Science. We will briefly discuss the history of these approaches, although we recognize that this may not be an exhaustive list because of the highly multidisciplinary nature of this research area.

2.2.1 Psychology

In the late 1990s, Psychology was dominated by psycho-analysis and behaviorism that focused on a "mental illness" model of human functioning. Positive Psychology was then

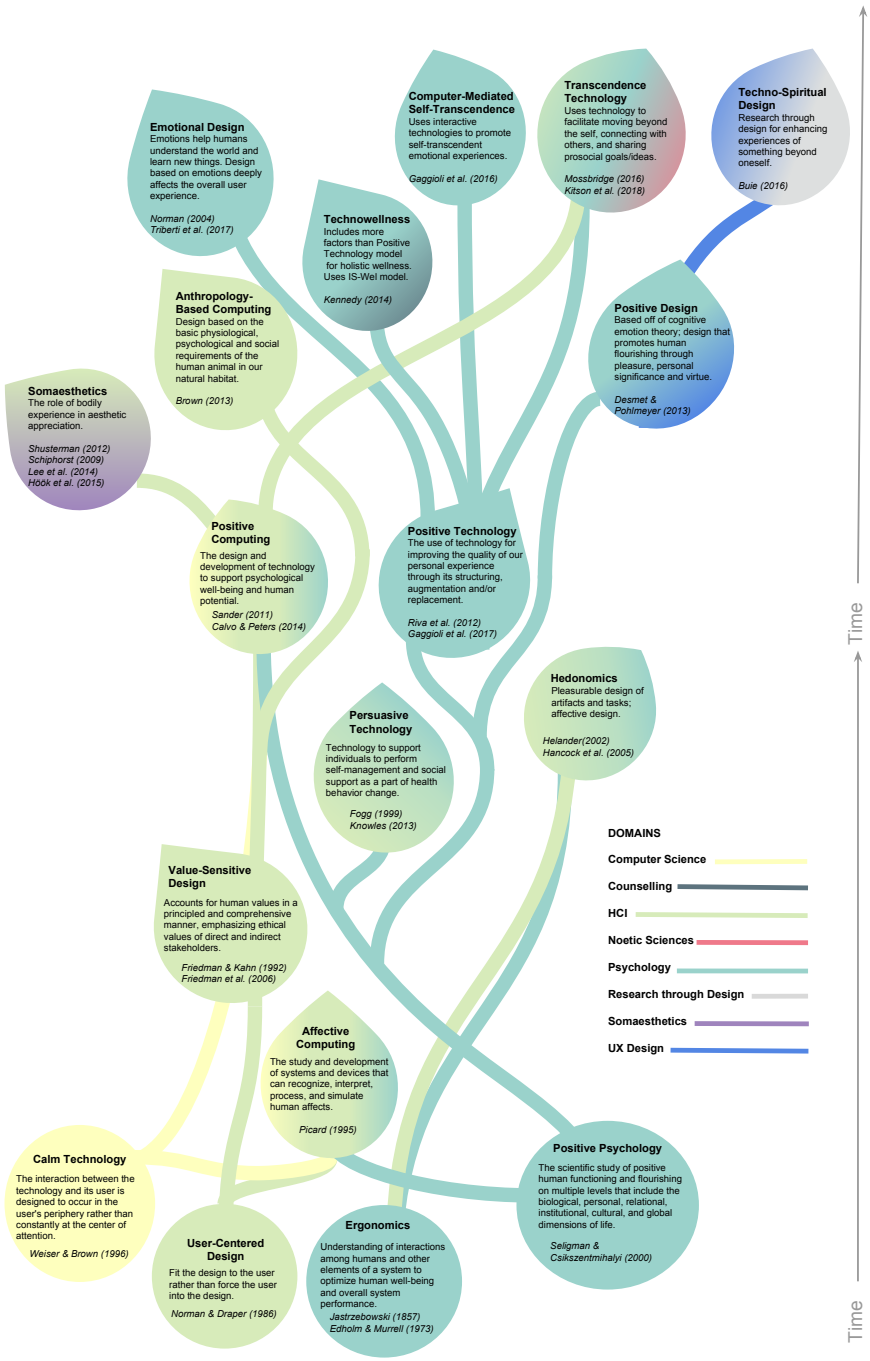

Figure 2.1: Existing domains of technology for positive functioning and well-being: moving along the y-axis is the passage of time on a non-linear scale that depicts the growth of different fields that stem from the foundational three domains of Computer-Science, HCI, and Psychology. Each color represents a different domain; the stems show the progression of the domain, feeding into the next; and the leaves are colored by the influences from those domains. Leaves represent the first conceptualization of an approach, and do not imply the cessation of progress, e.g., Affective Computing was first introduced in the 1990s and is still relevant today.

introduced as a counter to this way of thinking; instead it emphasized happiness, well-being and positivity. Positive Psychology originated with Seligman's PERMA theory and Csikszentmihalyi's Flow theory. PERMA consists of five elements that can help people reach a life of fulfillment, happiness, and meaning: Positive emotions, Engagement, Relationships, Meaning, and Achievement. Flow is an activity with goals/progress, feedback, and balancing perceived challenge and skill. Together, these two theories then formed the basis of several positive technology approaches including Persuasive Technology, Positive Computing, and Positive Technology. Fogg (1999) was one of the first researchers to put forth the idea that computers are able to persuade or change the behavior of people. Later, Knowles (2013) expanded upon this idea by placing importance on implicit values of both the user and designer to motivate behavior change. Positive Computing and Positive Technology both arose as ideas around the same time and are highly related (Gaggioli et al., 2017). Both consider ways for bringing well-being considerations into interaction design through positive technology theories. One difference is that Positive Computing (Calvo and Peters, 2014; Sander, 2011) uses an engineering lens for considering well-being in any technology either as preventative or active integration, whereas Positive Technology (Riva et al., 2012) uses a psychological lens for considering technology as a platform for supporting and sustaining well-being and the process of change. TechnoWellness (Kennedy, 2014) emerged in response to Positive Technology, arguing that Positive Technology was missing key factors for holistic wellness based on a counselling perspective that uses the IS-Wel model (Myers and Sweeney, 2005). The IS-Wel model, or Indivisible Self Model of Wellness, integrates both the model of the Indivisible-Self and the five factor Wellness Wheel. Emotional Design emerged with this effort to promote positive emotions or pleasure in users (Norman, 2004), and has since been expanded upon to the design of interactive technologies (Triberti et al., 2017). Directly stemming from Positive Technology came Computer-Mediated Self-Transcendence (Gaggioli et al., 2016), which is a more specific pathway of Positive Technology that focuses on interactive technologies to support self-transcendent emotional experiences. Similar to Computer-Mediated Self-Transcendence, Transcendence Technology (Mossbridge, 2016) seeks to use technology to move beyond the self and connect with others, but was developed more through a noetic sciences, i.e., parapsychological, lens. A specific example of Transcendence Technology is the study of lucid dreaming to inform the design of virtual reality introspective experience (Kitson et al., 2018). Desmet and Pohlmeyer (2013)took cognitive emotion theory and combined it with user experience (UX) design to form the framework of Positive Design, design that promotes human flourishing. A few years later, Buie (2016) formed Techno-Spiritual Design. Seemingly not wanting to use any of the existing theories on designing technology for well-being, Buie used a research through design approach to actively engage the user throughout the design process of creating technological experiences that support going beyond the self.

2.2.2 Human-Computer Interaction (HCI) and Computer Science

The idea of understanding human nature in relation to work has been around for a long time. In 1857, Jastrzebouski (2000) first coined the term ergonomics, referring to worker productivity in labor, entertainment, reasoning, and dedication. More contemporarily, ergonomics was reintroduced in the 1970s by Murrell (Edholm and Murrel, 1973) to mean understanding human-system interactions to optimize human well-being and system performance. Ergonomics then took on many different forms and specialties including cognitive ergonomics that encompasses usability, human-computer interaction (HCI), and user experience (UX) design. Some researchers viewed Ergonomics as focusing on negatively framed constructs such as pain prevention, particularly in the workplace. In order to look at the same human-technology interaction problem from a different perspective, a group of researchers created Hedonomics, the science and design devoted to the promotion of pleasurable human-technology interaction (Hancock et al., 2005; Helander, 2002). In the mid 1980s, the term User-Centered Design was first coined by Donald A. Norman's work in their lab (Norman and Draper, 1986). This concept focused on putting the user's needs and wants at the forefront of the product rather than trying to force the user to adapt their existing behaviours. User-Centered Design was soon adopted into many fields as a way to incorporate user feedback throughout the design process and not only at the evaluation phase as was originally used. Friedman and Kahn Jr (1992) introduced Value-Sensitive Design–developing technology by making decisions based on implicit and explicit values, and that values of both designers and users should be accounted for. Value-Sensitive Design guidelines were eventually developed with an ethical values framework in mind (Friedman et al., 2008). Meanwhile, in the domain of computer science, Weiser and Brown (1996) were developing a framework for designing the interaction between technology and user that had the technology seamlessly integrated without constantly being at the center of attention – Calm Technology. At the same time, Affective Computing used both physiological and psychological theories and both computer science and HCI lenses to support the design of technology that recognizes, interprets, processes, and simulate human affect (Picard, 2010). The seeds of both Computer Science and HCI contributed to fields of Positive Computing and Persuasive Technology as well (discussed above). Two other fields that emerged from the domain of HCI are Somaesthetics (Schiphorst, 2009; Shusterman, 2012) and Anthropology-Based Computing (Brown, 2013). Somaesthetics grounds itself in human bodily experience and movement to inform design, particularly the aesthetics of interaction. This approach has been adopted by many designers of technologies that support positive human functioning (for example: (Höök et al., 2015; Lee et al., 2014)). Anthropology-Based Computing uses basic human behaviour in our natural habitat as a basis of designing technological systems.

2.2.3 Motivation

Overall, following the emergence and the advances in the field of human-computer interaction, many different research domains have been focusing on designing for human-technology interactions that support positive human functioning and well-being, as discussed above. The foci of HCI research have been greatly concerned with the question: How to aid and mediate the interaction between a user and a system in such a way to allow for more efficient accomplishment of a task, that being retrieving the information, or alleviating states (e.g., stress) that can prevent them from accomplishing a task. Furthermore, early technological developments were focused on performance and production from an Engineering and Computer Science standpoint of usability and information retrieval. With the advent of the informational age, HCI and Psychological theories came together to ground human-technology interactions in genuine human experience, emphasizing the stance of the user over the system. We can see these ideas and framework permeate into the UX and design space, leading to current trends of using immersive, interactive technologies for providing experiential accounts mediated through technologies that support positive human functioning and well-being. However, there is not a clear understanding of what this design space looks like and how we might move forward with all these approaches in mind. In continuing the trajectory laid out in Figure 2.1, we seek to understand how immersive, interactive technologies might elicit positive states and support positive change. We found that there exist a few review articles on interactive technologies for supporting mindfulness (Sliwinski et al., 2017), transcendence (Mossbridge, 2016), and health (Botella et al., 2017). However, there does not seem to be comprehensive reviews looking at immersive, interactive technologies in eliciting positive states and supporting positive change. This motivated us to perform a scoping review in order to explore the extent of the literature in this domain, and potentially inform the scope of a future systematic review. While mindfulness may fit into the idea of positive states and positive change, we differentiate ourselves by expanding and including immersive, interactive experiences that support people on hedonic, eudaimonic, and social/interpersonal levels, which are the three positive technology domains as put forth by Riva et al. (2012). Hedonic relates to pleasant sensations, eudaimonic focuses on meaning and self-realization, and social/interpersonal involves relations or communications between people. We emphasize the focus on immersive technologies because they have a high potential of influencing and transforming the user through increased presence, the physical feeling of being in the simulated environment, which then enhances the experience's effectiveness (Cummings and Bailenson, 2016; Diemer et al., 2015; Riva et al., 2007).

2.2.4 Defining Immersive, Interactive, and Well-being

The term "immersion" has been discussed and used by researchers in the technology field for decades, yet there seems to still be some confusion because the term is so widely used to

describe experiences in games (Brown and Cairns, 2004; Ermi and Mäyrä, 2005), paintings (Garau et al., 2003), literature (Nell, 1988), and cinema (Bazin, 1967). Defining immersion is critical to our understanding of the relationship between the user and the virtual environment because it addresses the very notion of being in the context of such simulated environments (Grimshaw, 2014). Moreover, without a clear definition of the concept, results can be uninterpretable. Some researchers, particularly in the gaming field, view immersion as different facets: sensory-motoric immersion, cognitive immersion, emotional immersion, and spatial immersion (Bjork and Holopainen, 2005). Ermi and Mäyrä (2005) SCI model of immersion consists of three components: sensory, challenge-based, and imaginative. These models of immersion seem to suggest that immersion is a psychological process. However, contemporary researchers of immersion (IJsselsteijn et al., 2003; Rettie, 2004; Van den Hoogen et al., 2009) roughly follow Slater and Wilbur's definition of system immersion as

> a description of a technology... that describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the sense of a human participant (Slater and Wilbur, 1997) (p. 606).

Here, immersion appears to be less of a psychological process and more of a physical process where our bodies and senses are tricked into behaving and reacting like the virtual environment is real. A similar construct, presence, is then the psychological process of believing the virtual environment is real or the feeling of 'being there' (IJsselsteijn et al., 2003). Following these definitions of immersion and presence, virtual lucidity, a term defined by Quaglia and Holecek (2018) is when a person is immersed (the virtual environment feels real) yet not present (knows the virtual environment is not real). This review is focused on the psychological factors determining presence; we note, however, that there are different theoretical accounts on the definition of presence and which factors influence it (Coelho et al., 2006; Triberti and Riva, 2016). Aligning ourselves with contemporary definitions, we also chose to follow Slater and Wilbur's definition of immersive as an objective property of the technology for the purposes of this review.

Steuer (1992) defines interactivity as "the extent to which users can participate in modifying the form and content of a mediated environment in real time" (p. 14). Rubio-Tamayo, Barrio, and García have defined interactivity as

> the potential to receive information from the ensemble of our senses and to construct and configure an alternate reality or to simulate reality. Additionally, it is the potential to influence (in real time) in the digital environments, the objects and the narrative framed in it (Rubio-Tamayo et al., 2017) (p. 11).

Non-interactive technological experiences such as web-pages, video instructions, guided mobile apps, 360 videos, and movies were excluded from this review. These applications

can provide, from a certain point of view, a two-way flow of information between computer and user. However, they do not meet the definition proposed by Rubio-Tamayo et al. (2017) as having the potential to influence digital environments. Related to interactivity is the construct of embodiment, where cognition is shaped by the body (Markman and Brendl, 2005; Varela et al., 2017). Technologies can be embodied for their abilities to modify the cognitive factors regulating the experience of body and space (Riva et al., 2016).

Well-being refers generally to the interconnected dimensions of physical, mental, and social health of an individual. A few models in psychology attempt to understand and define well-being. First, is the broaden-and-build hypothesis that states positive emotions broaden people's momentary thought-action repertoires, and positive emotions build over time enduring psychological, intellectual, physical, and social resources (Fredrickson, 2001). Second, is the self-determination theory where autonomy, competence, and relatedness needs must be satisfied in order to foster well-being and health; and self-determined behaviour is intrinsically motivated (Ryan and Deci, 2000). Third, authentic happiness theory postulates that pleasant life, engaged life, and meaningful life are the three concepts needed for well-being (Seligman, 2002). However, several limitations were found with this theory, and so he developed PERMA-theory (Seligman and Csikszentmihalyi, 2000): **P**ositive emotions (happiness, joy, excitement, satisfaction, pride, awe); **E**ngagement (flow); **R**elationships (work, familial, romantic, platonic); **M**eaning (purpose); **A**ccomplishments (success and mastery). In this review, we consider all of these conceptualizations of well-being in an attempt to discover as many immersive, interactive experiences that support well-being as possible.

2.2.5 Objectives and Research Questions

We make four contributions in this paper.

First, we identify the design elements and interaction strategies that contribute to well-being and positive affective states. And, in this process, we unveil design nuances and note the obstacles users encounter in interacting with the particular XR technology, a term which includes virtual, augmented, and mixed realities. Second, we identify the input-output modalities of the system and the psychological outcomes of each study. Third, we present a framework for designing transformative experiences with immersive, interactive technologies whose goal is to elicit positive states and support positive human change. Fourth, we provide design considerations informed by the comparative analysis of the designs and a framework for future designs of positive interactive technologies with the goal of eliciting positive states and supporting positive change in users.

To assess the current state of the research in positive, immersive, interactive technologies, this scoping literature review will address two research questions:

RQ1: How can we most effectively employ different design elements and interaction strategies to support positive change in immersive, interactive technologies?

RQ2: What are the input and output modalities of immersive, interactive technologies that contribute to eliciting positive states?

2.3 Method

2.3.1 Scoping Review Protocol

We undertook this study as a scoping literature review based on guidelines proposed by Arksey and O'Malley (2005) and Levac et al. (2010). Scoping reviews are a process of mapping the existing literature or evidence base in order to identify research gaps and summarize research findings. Scoping reviews differ from systematic reviews in that they use broader research questions, inclusion/exclusion criteria can be developed post hoc, quality is not an initial priority, it may or may not involve data extraction, and synthesis is more qualitative and not typically quantitative (Armstrong et al., 2011). Still, both scoping and systematic reviews require rigor and time to complete. We decided on a scoping review over a systematic review because our research questions are explorative and our objective is to map the literature with a broad viewpoint, rather than to respond to narrow research questions. We registered our review on PROSPERO – registration # CRD42018082752. The following steps were taken in accordance to the scoping guidelines:

1. Identify the research questions,
2. Identify relevant studies,
3. Study selection,
4. Charting the data,
5. Collating, summarizing, and reporting results.

2.3.2 Identifying Relevant Studies

A systematic search of the literature was performed in four academic databases that were considered the most relevant due to their focus on HCI: ACM Digital Library, Web of Science, Design and Applied Arts Index (DAAI), and IEEE Xplore (IEEE/IET Electronic Library). Google Scholar was used as an additional academic search engine to ensure all relevant articles were found. The search was focused on immersive and interactive technologies and experiences, which included virtual, augmented, and mixed realities, otherwise known as "XR". The XR experiences were related to positive well-being and not on clinical interventions relating to treating disease. We sought articles from any time until January 2018, the end of this search. We utilized the retrieval of relevant articles with the following search terms based on the definitions of immersive, interactive, and well-being for technologies:

("immersive" OR "interactive" OR "virtual realit*" OR "augmented realit*" OR "mixed realit*" OR "extended realit*") **AND** ("well-being" OR "wellbeing" OR "well being" OR "wellness" OR "positive" OR "emotion*" OR "social" OR "autonomy" OR "competence" OR "relatedness" OR "pleasant" OR "engag*" OR "meaning*" OR "happiness" OR "joy" OR "excitement" OR "satisfaction" OR "pride" OR "awe" OR "flow" OR "relationship*" OR "purpose" OR "success" OR "mastery")

The first part of the search index includes technologies that are immersive and interactive. The second part includes terms taken directly from well-being theories: broaden-and-build model (Fredrickson, 2001), self-determination theory (Ryan and Deci, 2000), authentic happiness theory (Seligman, 2002), and PERMA theory (Seligman, 2011). We also decided to include the following search terms, which were part of a sub-search, based on the theoretical approaches we described in the introduction and list in Figure 2.1 because they are directly related to supporting positive human functioning and well-being with technology:

("tech*" OR "computing") **AND** ("change" OR "support tool" OR "connection" OR "calm*" OR "essential self" OR "transcenden*" OR "transformative" OR "self-transcend*" OR "consciousness hacking" OR "UX for good" OR "spiritual" OR "persuasive" OR "lovingkindness" OR "metta" OR "mindful*" OR "meditat*")

We applied this search string to the title, abstract, full-text, and author keywords. Applicable articles were also identified through backward reference searching, i.e., by screening the reference lists of retrieved publications. Google Scholar was utilized for the backward reference searching to run general searches of specific references and to identify relevant articles.

2.3.3 Study Selection

Peer-reviewed articles as well as scholarly work such as dissertations, theses, and conference proceedings with the following characteristics, published from the beginning of the literature until January 2018, were included:

- written in English,
- having at least one immersive and interactive technology,
- having a goal to improve well-being.

We included other scholarly work, i.e., dissertations, theses, and conference proceedings, because these works were also relevant to the field, they often report studies that can be important for our research questions, and we wanted to be comprehensive in our study

selection. Blog entries and websites, although can be insightful and managed by scholarly affiliations, were excluded because they often do not report studies and are difficult to compare to other literature types. Immersive, interactive technologies were chosen as the appropriate setups in order to keep the review the most up to date, and because they are relevant for transformative experience design. The immersive, interactive experiences themselves needed to include a well-being component or focus on positive human functioning in order to relate to the core elements of transcendent experiences. Consequently, articles with the following characteristics were excluded:

- using exclusively desktop-based, tablet-based, or mobile virtual environments,
- non-interactive experiences,
- addressing solely conceptual matters, such as theoretical models, frameworks, reviews, etc,
- using immersive, interactive technology as a tool for studying a different, unrelated topic.

The screening process and its results are visualized in Figure 2.2. The first and second author screened the results independently and then compared agreement. If there was a discrepancy, then the third author was consulted. The initial search elicited 984 articles from the four databases and 4 from the reference review, which were retrieved with Google Scholar. 103 duplicates were identified and removed, leaving 885 articles to be screened. The initial screening of studies was based on their abstracts and titles, excluding noticeably irrelevant studies based on the inclusion/exclusion criteria listed prior. In total, 209 articles were identified as appropriate for inclusion, and they were moved to the second screening round. The second round of screening was based on the full text of the articles and the first and second authors independently reviewed each using the inclusion/exclusion criteria set before the search, as suggested by Levac et al. (2010). In total, 29 articles were identified as appropriate for inclusion and relevant to the current review. The authors reviewed all 29 articles independently. All reviewers together conjointly shaped the categories and themes of the review, based on the data extraction process. The authors discussed and settled any disagreements of the qualitative synthesis of the review before writing the final narrative.

2.3.4 Charting the Data

The screening process resulted in 29 articles that satisfied the inclusion criteria. The data extracted from each article were the following:

1. source and full reference
2. description and name of the immersive interactive system

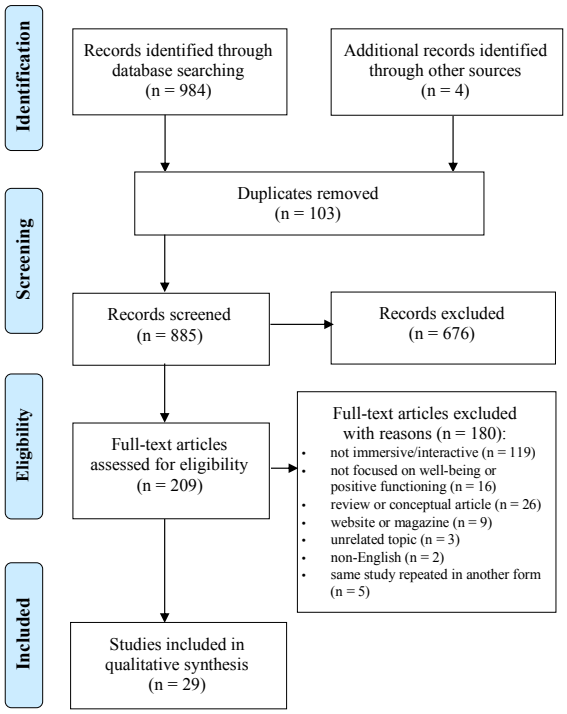

Figure 2.2: Flowchart of the included and excluded articles from the assessment of screening and eligibility process.

3. relevance to well-being and positive functioning
4. type of XR
5. technology used
6. platform
7. target user
8. number of users in study
9. input / output modalities
10. design elements and interaction strategies used
11. outcome
12. how design elements and interaction strategies contributed to support positive change and/or elicit positive states

See supplementary material for a detailed table of the data extracted. If data were missing, the study authors were contacted. The first author performed the data extraction process.

2.3.5 Collating, Summarizing, and Reporting the Results

The collected data were synthesized by identifying themes emanating from information reported in each accepted paper and related to the research questions. Themes were classified into a concept matrix to facilitate comparisons. A concept matrix provides the transition from an author-to-concept-centric literature review, provides structure and helps in clarifying the concepts of the review for the reader. The main themes identified were as follows:

- The design elements and interaction strategies used (addressing RQ1)
  - the article's relevance to positive functioning
  - how these elements and strategies support positive change
- Input/output modalities (addressing RQ2)
  - the type of XR,
  - the technology used,
  - the platform,
  - the outcome

These themes were based on the description provided in the articles, as crosschecked with other related and/or peer reviewed publication in the field to establish their scientific soundness, mainly towards nomenclature and interaction features. Next, the identified themes were normalized and classified so they would be easily comparable and fit into the concept spreadsheet in a valid and lossless way. Comparative studies that included two or more immersive, interactive experiences were tabulated in a respective number of rows.

In order to assess risk of bias (quality), we used the Downs and Black 26-item QAT scale (Downs and Black, 1998). A review article looked at 60 research evaluation systems and identified the Downs and Black checklist as one of the best evaluation systems available (Deeks et al., 2003). The Downs and Black checklist provides an overall quality index and four sub-scales of quality assessment: reporting, external quality, internal validity bias, and internal validity confounding. Answers are scored 0 or 1, except for one item that scored 0 to 2 making the maximum score possible 27. Generally speaking, scores are considered "excellent" (24–28 points), "good" (19–23 points), "fair" (14–18 points) or "poor" (<14 points).

2.4 Results

Of the 29 articles found in the scoping review process, some articles contained multiple systems and studies. Thus, we documented 33 immersive, interactive experiences relating to positive human functioning. However, we excluded 13 of those 33 XR experiences in the

Downs and Black analysis because they were only proof of concept and did not have any participants, thus rendering the scale irrelevant. Therefore, we examined the remaining 20 experiences using the Downs and Black QAT scale. For the overall quality index, i.e., all 26 items comprising all sub-scales, a maximum score of 27 was possible. For the 20 experiences examined, the average overall quality index was 17.4 (SD=2.96) with scores ranging from 12-23. Based on interpretations of this scale, these studies are considered fair to good with only one study performing poorly in terms of validity and reliability. One possible reason for the wide spread of scores is because the studies were for different audiences. For example, a psychology study might use similar metrics to the Downs and Black scale to assess quality and thus have a higher score compared to a user study or art installation that uses a different set of metrics to assess quality. Moreover, this metric was designed for medical intervention studies, which require a high degree of methodological quality; this is not necessarily the aim many of these articles we found here. Nonetheless, these results do show the range in methodological quality in the field and perhaps in the future researchers might consider using a similar metric to provide more rigor in their user study analyses.

2.4.1 Design Elements and Interaction Strategies

The 12 main themes that inform the design elements and interaction paradigms of the 33 documented immersive, interactive experiences are presented as follows.

- **Breath awareness**: Users' respiration data (inhale/exhale cycle) were recorded through either a respiration belt or microphone. These data were then employed in interaction design for users to become more mindful of their bodily processes (Bal, 2013; Davies and Harrison, 1996; Du Plessis, 2017; Hinterberger, 2011; Kitson et al., 2014; Muñoz et al., 2016; Prpa et al., 2015, 2016, 2017; Roo et al., 2016; Shaw et al., 2007; Vidyarthi, 2012) or achieve a relaxing state (Patibanda et al., 2017; Van Rooij et al., 2016).

- **Concentration or focused attention**: Users' awareness of the present moment was supported through design that helps users bring their attention back when they have distracting thoughts. This was achieved explicitly through biofeedback (Amores et al., 2016; Kosunen et al., 2016; Muñoz et al., 2016; Prpa et al., 2015, 2016; Shaw et al., 2007) or implicitly by visual or auditory cues (Gu and Frasson, 2017; Navarro-Haro et al., 2017).

- Connection: Users can feel a sense of belonging and relatedness through telepresence and communication (Angelini et al., 2015; Bernal and Maes, 2017; Garau et al., 2003; Quesnel and Riecke, 2017; Sakamoto et al., 2015; Seaborn, 2016).

- **Emotional expression**: Emotions of the users can be expressed through audio and visual mappings, mainly through capturing physiological markers such as arousal (Bernal and Maes, 2017) and joy (Hinterberger, 2011).

- **Feedback of performance**: Users received some form of information about their performance. Feedback was given as virtual movement (Amores et al., 2016; Davies and Harrison, 1996; Du Plessis, 2017; Kosunen et al., 2016), change in visuals (Bal, 2013; Choo and May, 2014; Gromala et al., 2015; Hinterberger, 2011; Kosunen et al., 2016; Patibanda et al., 2017; Prpa et al., 2015, 2017; Roo et al., 2016; Shaw et al., 2007; Van Rooij et al., 2016), or change in audio (Gu and Frasson, 2017; Hinterberger, 2011; Kitson et al., 2014; Muñoz et al., 2016; Prpa et al., 2015, 2016, 2017; Shaw et al., 2007; Vidyarthi, 2012).

- **Mind-body dialogues**: Users were able to explore the connection between their physical and mental states, the idea being that one similarly affects the other. A calm body breeds a calm mind: (Bal, 2013; Du Plessis, 2017; Gromala et al., 2015; Kosunen et al., 2016; Muñoz et al., 2016; Prpa et al., 2015; Roo et al., 2016; Shaw et al., 2007; Van Rooij et al., 2016). To change ourselves, we need to change our perspectives: (Davies and Harrison, 1996). Colour transmits and translates emotion (Hinterberger, 2011; Wiethoff and Butz, 2010). Music is the mediator between the spiritual and the sensual life: (Kitson et al., 2014; Prpa et al., 2016, 2017; Vidyarthi, 2012).

- **Mindfulness meditation**: These experiences involved paying attention on purpose, in the present moment, and nonjudgmentally. Users were guided through a narration (Choo and May, 2014; Gu and Frasson, 2017; Navarro-Haro et al., 2017; Prpa et al., 2015; Shaw et al., 2007) or had the chance to playfully discover meditation practice unguided (Amores et al., 2016; Bal, 2013; Davies and Harrison, 1996; Du Plessis, 2017; Gromala et al., 2015; Kitson et al., 2014; Kosunen et al., 2016; Prpa et al., 2016; Roo et al., 2016; Vidyarthi, 2012), while another experience incorporated but was not explicitly about mindfulness meditation (Chittaro et al., 2017).

- **Movement**: Users physically moved their bodies in order to interact with the system. Movement was used as a way to promote health (Eubanks, 2011; Seaborn, 2016) and also further immerse the user in the virtual space through embodiment (Bal, 2013; Davies and Harrison, 1996; Quesnel and Riecke, 2017; Sakamoto et al., 2015).

- **Nature elements**: These experiences involved some aspects of nature. Some experiences used water as a visualization (Bal, 2013; Gu and Frasson, 2017; Prpa et al., 2017; Sakamoto et al., 2015; Van Rooij et al., 2016), while others used animals (Eubanks, 2011; Sakamoto et al., 2015; Shaw et al., 2007). A common theme was using park or garden elements (Angelini et al., 2015; Chittaro et al., 2017; Choo and May, 2014; Roo et al., 2016), while other experiences focused more specifically on trees and

the forest (Davies and Harrison, 1996; Gromala et al., 2015; Patibanda et al., 2017). One experience used a sunset scenery (Shaw et al., 2007), and another used the entire Earth (Quesnel and Riecke, 2017).

- **Physiological measures**: Use of instruments that provide information on physiological functions in order to gain greater awareness of internal states of a user. The processes can include brainwaves (Amores et al., 2016; Choo and May, 2014; Du Plessis, 2017; Gu and Frasson, 2017; Hinterberger, 2011; Kosunen et al., 2016; Prpa et al., 2015, 2016), skin temperature and conductance (Bernal and Maes, 2017; Du Plessis, 2017; Gromala et al., 2015; Hinterberger, 2011; Shaw et al., 2007), respiration (Bal, 2013; Davies and Harrison, 1996; Du Plessis, 2017; Hinterberger, 2011; Kitson et al., 2014; Patibanda et al., 2017; Prpa et al., 2015, 2016, 2017; Roo et al., 2016; Shaw et al., 2007; Van Rooij et al., 2016; Vidyarthi, 2012), and heart rate and heart rate variability (Bernal and Maes, 2017; Chittaro et al., 2017; Hinterberger, 2011; Muñoz et al., 2016; Roo et al., 2016; Shaw et al., 2007).

- **Playfulness**: Users were invited to interact with the system that supports curiosity and creativity in order to make the experience as inviting and non-invasive as possible. This was achieved through exploring a narrative (Amores et al., 2016; Eubanks, 2011; Muñoz et al., 2016), employing gaming mechanics (Choo and May, 2014; Muñoz et al., 2016; Patibanda et al., 2017; Sakamoto et al., 2015; Seaborn, 2016; Van Rooij et al., 2016), and using active and imaginative elements (Hinterberger, 2011; Kitson et al., 2014; Prpa et al., 2015, 2016, 2017; Roo et al., 2016; Vidyarthi, 2012; Wiethoff and Butz, 2010).

- **Social presence**: Users interacted with other users at the same time (Angelini et al., 2015; Bernal and Maes, 2017; Sakamoto et al., 2015; Seaborn, 2016) or avatars that felt as if they were real people (Garau et al., 2003).

Physiological measures (N=21), feedback loop (N=19), and mind-body dialogues/ mindfulness-meditation/ play (all N=16) were the design elements or interaction strategies most utilized. These results can inform the answer to RQ1.

2.4.2 Input / Output Modalities

To address RQ2, we extracted the input-output modalities of the experiences, the type of XR, the technology employed, and the platform used. The type of XR and technology employed can be seen in Figure 2.3. For a more detailed description of these data, we also created a table (see Supplementary Material) that shows both the technology and the platform used by each system individually, grouped by XR type. In terms of the input-output modalities, we grouped all the immersive, interactive positive experiences and categorized them into three high level themes: biofeedback, physical movement,

and controller. Within each of these three high level themes were different input modalities. For biofeedback, this contained four types of inputs: blood flow changes, skin electrical activity, respiration rate, and brain electrical activation (see Figure 2.4). The physical movement theme contained three input types: arm, body, and head. The controller theme had two input types: joystick and screen. We then mapped these inputs to output modalities. We grouped the outputs into six different themes: change in music/audio, change in light/colour, change in object appearance/animation, object movement, levitation/floating, and user movement. Finally, we mapped the six different types of outputs to 16 types of outcomes: relaxed, content/happy, reflected affect, increased mindfulness, harmony/balance, appreciation, calm, decreased stress/anxiety, connection/empathy, clarity, focus, increased well-being, emptiness/disembodied/self-transcendence, engaged, presence/social presence/embodied, and increased risk perception. A depiction of the input-output-outcome modalities can be found in Figure 2.5 and also accessed online here: `https://akitson.github.io/`

2.5 Discussion

Immersive interactive technologies have, so far, mainly been developed for applications such as entertainment and training. However, the potential for these technologies is vast and we are beginning to see the direction of the field shift toward more experiences of supporting positive human functioning and change (Brown, 2013; Buie, 2016; Desmet and Pohlmeyer, 2013; Fogg, 1999; Gaggioli et al., 2016; Kennedy, 2014; Mossbridge, 2016; Riva et al., 2012; Sander, 2011; Schiphorst, 2009). There are similar, yet separate, movements from different domains such as HCI, Psychology, and Computer Science all going toward this same goal of designing and creating technologies that support positive human functioning (Norman and Draper, 1986; Seligman and Csikszentmihalyi, 2000; Weiser and Brown, 1996). Yet, there is not a clear overview of all of these domains and what they have contributed so far. The diversity of the domains could be one reason there has not been a general XR for positive change review. In general, the current scoping review showed that the recent resurgence of XR technologies that are low-cost and accessible offered an opportunity to explore the medium further. Moreover, it enabled designers and technologists that ability to create more experiences, thus providing grounds for a comparison and analysis of the design elements and interaction strategies used, as well as the input-output-outcome modalities. Overall, the authors find this review shows promise for a new era of XR for positive change and that there exist enough experiences for researchers to map it and further develop significant conceptual knowledge for the research community and the public.

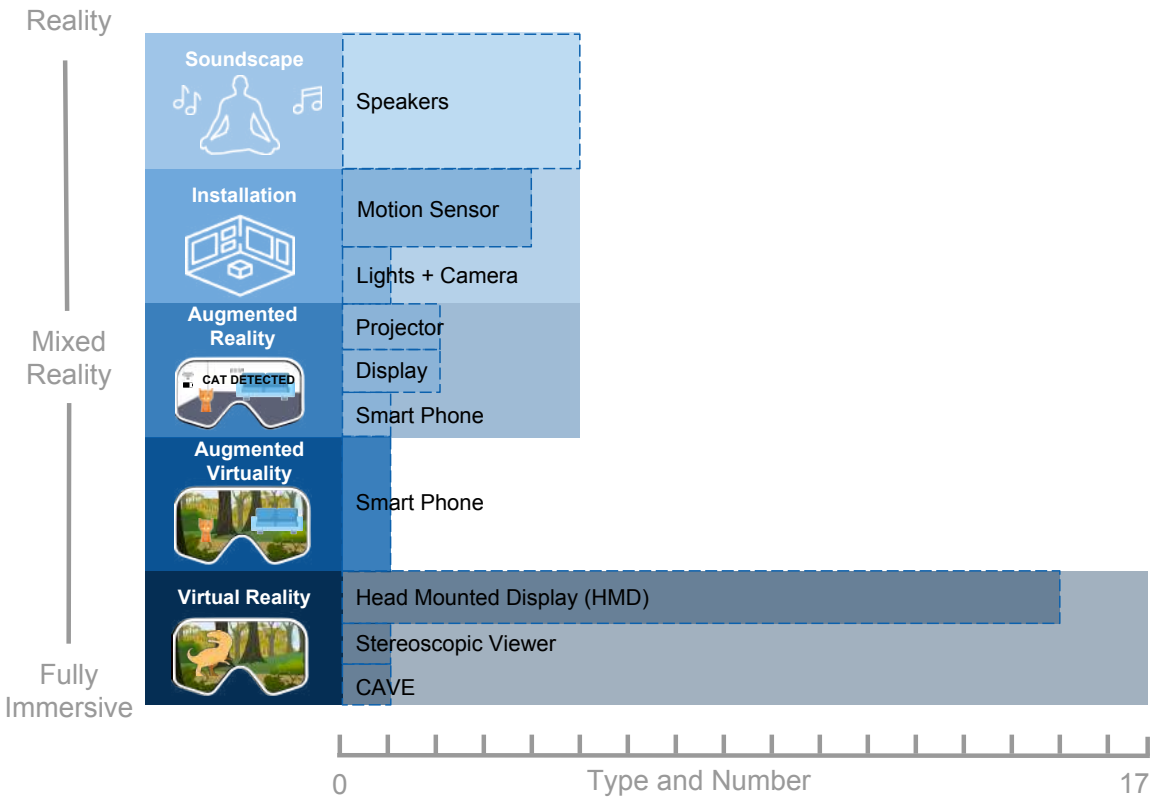

Figure 2.3: The type and number of immersive, interactive experiences for positive functioning (x-axis). Types of immersive, interactive experiences are categorized on a virtuality continuum (y-axis) that increases in immersive properties from soundscape (least immersed) to virtual reality (fully immersed). Each type is broken down into the kind and number of technology used, and this is represented as the dotted bars within the larger bars representing the total number of experiences.

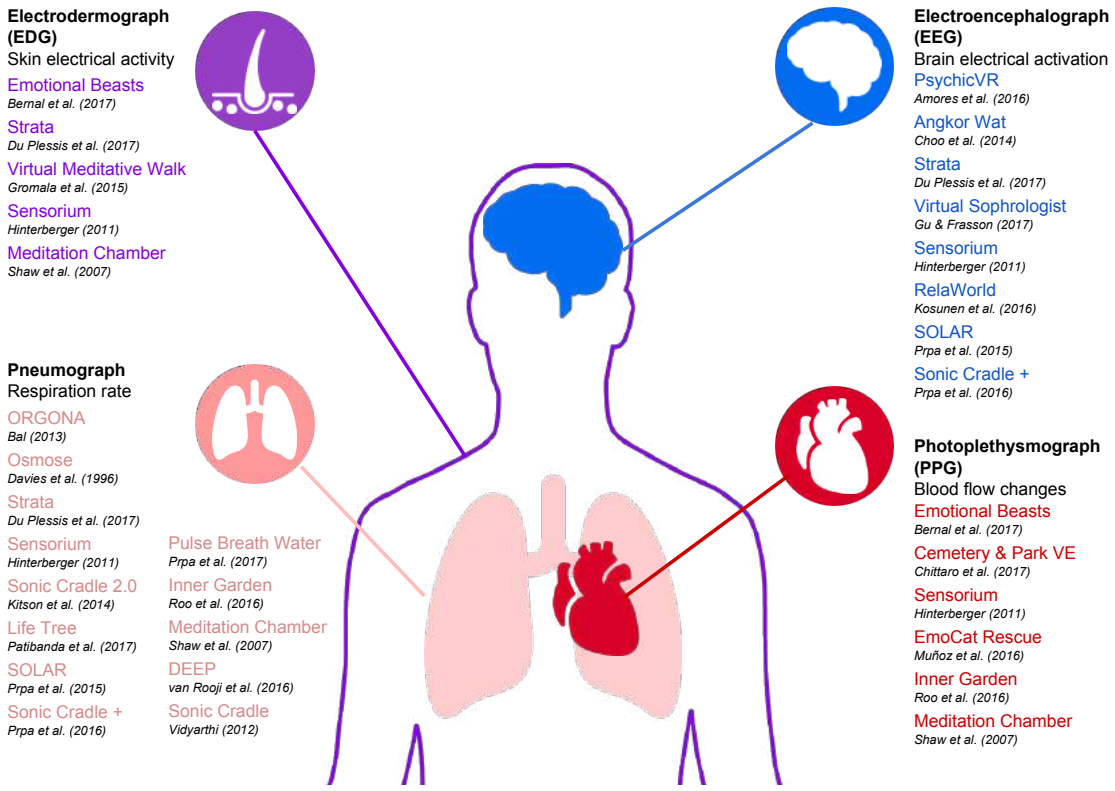

Figure 2.4: Biofeedback types and their corresponding immersive, interactive experiences. There are four types of biofeedback represented: electrodermograph (EDG), pneumograph (respiration rate), electroencephalograph (EEG), and photoplethysmograph (PPG). The names of the experience along with the author's name is listed. Some experiences are listed multiple times, indicating they used multiple types of biofeedback in their system.

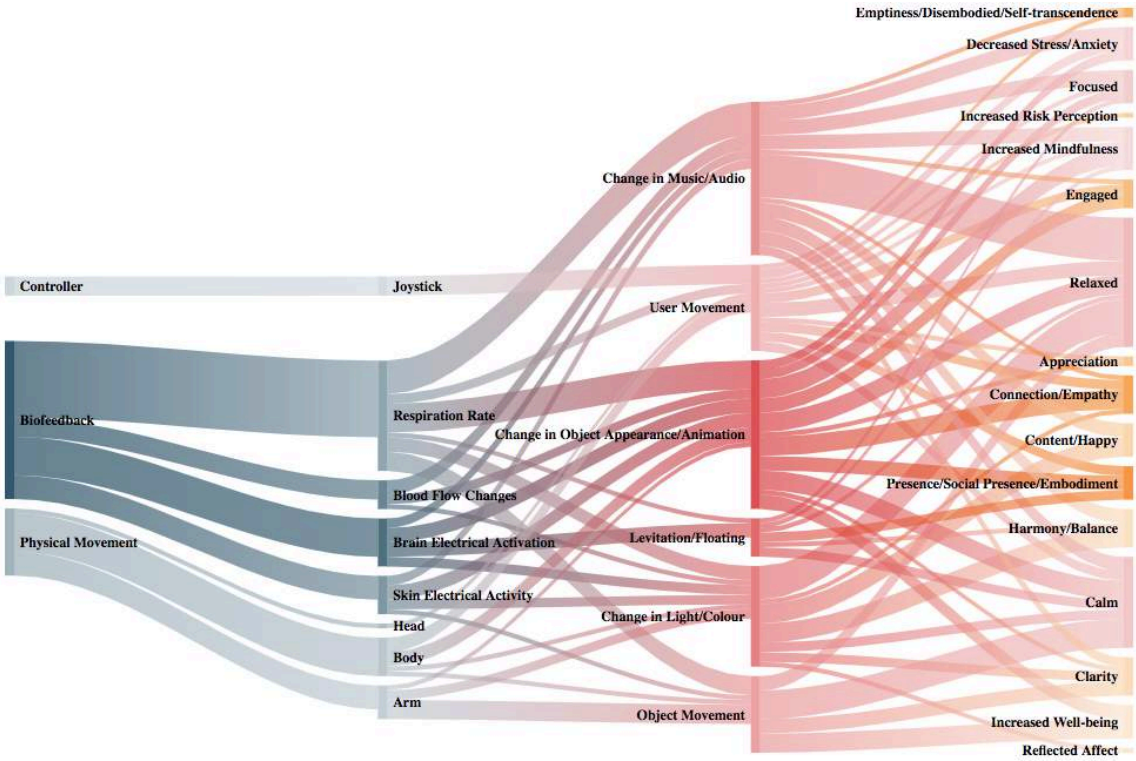

Figure 2.5: Sankey diagram showing the input-output modalities and their corresponding outcomes for all experiences. Please note that some experiences use multiple types of input-output modalities, and some inputs correspond to multiple outputs and outcomes. Color intensity and stroke breadth indicate number of experiences for that category going left to right. This figure represents a static image of the data. For an interactive diagram that shows the number of experiences for each category, please see `https://akitson.github.io/`.

2.5.1 Design Elements and Interaction Strategies for Supporting Positive Change in Immersive, Interactive Technologies

We can make several observations from the reviewed and studied XR design elements and interaction strategies in section 3.1. We have organized the above 12 themes into four higher-level themes: instruments of analysis, phenomena and theoretical constructs, content features, and physical activity.

2.5.1.1 Instruments for Analysis

First, **physiological measures** and **feedback of performance** are the most prevalent elements. There is considerable overlap between these two elements with all but one experience making use of physiological measures as a means to provide feedback on performance. Since its inception in the 1970s, biofeedback has been gaining popularity due to its use as a supporting mechanism that can offer explicit insights about the user's state and can guide a user to change their thoughts, emotions and behaviour (Schwartz and Andrasik, 2017). However, biofeedback has been mainly used as a form of treatment in medicine and psychology and we have only recently seen more applications to immersive, interactive experiences; and this may be in part due to the dispersion of increasingly affordable and consumer-friendly physiological devices. The literature review also showed a preference for experiences using mind-body dialogues and mindfulness meditation interaction strategies. Both of these elements emphasize focusing on the body and noticing any sensations, thoughts or feelings that happen in the present moment (Kabat-Zinn, 2003). Studies have shown numerous benefits for mindfulness meditation such as reducing depression symptoms, stress, and anxiety (Chiesa and Serretti, 2010). Moreover, the same mindfulness processes understood by Buddhist traditions for many years have been brought to psychology and now to human-computer interaction design. Thus, it is perhaps not surprising that immersive, interactive technologies make use of these concepts to support positive change because they can provide a space one might not otherwise have access to explore their own internal bodily states. In fact, many experiences from the review also made use of two elements very closely related to mindfulness and mind-body dialogues: breath awareness and concentration or focused attention. Breath is often seen as an integral part of mindfulness meditation because it provides a focus point to bring one's attention back to the present moment when the mind wanders. Thus, bringing one's attention back to the breath, or some other focus of attention, works the mind and we gain more control over our internal states with each practice.

2.5.1.2 Phenomena and Theoretical Constructs

Another observation is that **emotional expression**, **connection**, and **social presence** are not studied or utilized as much as mindfulness meditation. One might expect more

experiences with these elements given both that social integration and connectedness are important components in many psychological frameworks of well-being and positive human functioning (Ryff, 1989; Seligman and Csikszentmihalyi, 2000; Venter, 2017), and that there is a movement in several domains to use technology as more than a distraction or consumption device and instead use it to connect with others as a part of health behaviour change (Brown, 2013; Calvo and Peters, 2014; Kennedy, 2014; Mossbridge, 2016; Riva et al., 2012). Moreover, Höök has proposed the affective loop, where the system affects the user and the user affects the system (Höök, 2008). This represents a gap that can be addressed by future developments of immersive, interactive technologies for positive change.

2.5.1.3 Content Features

Nature was another common design element in the immersive, interactive experiences we reviewed. Research evidence suggests that connecting with nature is one path to flourishing in life and positive mental health (for a review see: (Capaldi et al., 2015). We found similar benefits of enhanced mood, reduced stress, and increased well-being across the XR experiences that involved nature. Thus, it appears that the benefits of being in contact with nature can be replicated in a virtual or augmented environment. This is promising for using XR experiences to help support positive change for those who cannot have much access to nature or the outdoors, such as those in urban areas or in medical facilities.

2.5.1.4 Physical Activity

Finally, about half of the experiences included in this review used the interaction strategies of **play** and **movement**. We can draw similarities between these elements and several existing theories: somaesthetics, the importance of the role of bodily experience in aesthetic appreciation (Schiphorst, 2009; Shusterman, 2012); embodied cognition, our mental constructs are shaped by aspects of the body (Markman and Brendl, 2005; Varela et al., 2017); play, in being creative we can reach across domains of meaning and forge new conceptual connections leaning to insight or cathartic release (Clark, 2013); and game play, gaming activities embody immense concentration, enjoyment, relationships, and accomplishment that can lead to improved mood, reduced emotional disturbance, improved emotion regulation, relaxation, and reduced stress (Jones et al., 2014). Future XR experiences aimed at supporting positive change would be strengthened by incorporating these theories from other disciplines because they have already demonstrated their effectiveness for supporting flourishing and positive mental health.

2.5.2 Input-Output Mappings of Immersive, Interactive Technologies for Eliciting Positive Change

2.5.2.1 Immersive, Interactive Technologies

The review of technologies and platforms focused strongly on virtual reality (VR) technology. Therefore, it is perhaps unsurprising that VR, particularly the use of head-mounted displays (HMDs), is the most prevalent type of technology that we find compared to other mixed reality experiences. Immersive soundscapes are the second most common type of technology used for eliciting positive states. The use of other XR technologies along the mixed reality continuum of immersion seem to have been overlooked. One possible explanation could be that HMDs are being made increasingly more affordable and accessible, while also improving in overall quality; other mixed reality technologies are still in their infancy and lack the development support for designers to more easily create experiences. The authors would like to emphasize that simply because VR is currently the most prevalent technology used in eliciting positive states does not necessarily mean it is the best platform. Each design requires careful consideration of the intended experience and specific outcomes when selecting a platform, taking into account the context and its users, and more research is needed for determining the "best" platform for eliciting positive change.

2.5.2.2 Input

The review of input-output modalities showed that physiological data was the most predominant type of input, followed by physical movement and then controller (see Figure 2.5). When breaking down the type of biofeedback used, we found that respiration rate was overwhelmingly the most utilized type (N=16). Measuring respiration rate is relatively non-invasive and the data is reliable compared to the other types of biofeedback such as EEG; this may partially account for its high use. As was discussed previously, breath is an important component in mindfulness meditation and a reliable way to decrease stress. Therefore, using respiration rate as an input is congruent with the mindfulness and mind-body dialogue interaction strategies used in these experiences for positive change. One observation we made about the type of input is that there was a low number of experiences using controllers, such as joysticks or touch screens. This might be surprising considering that much of the XR industry is being fueled by entertainment and gaming applications that make use of traditional controller-based inputs. This review perhaps demonstrates that traditional controllers do not map well to eliciting positive states. We hypothesize this is due to controllers' arduous nature that might lead to a break in presence, immersion and flow, and subsequently distracting from the goal of eliciting positive states. However, further research is needed. Physiological input was very prevalent in the studies and experiences we reviewed, with 34 instances of mappings involving physiological input. And, although there are many benefits to using physiological measures such as getting a more empirical

measures of users' inner states, there are also several shortcomings that we would like to highlight in this review for designers and research hoping to use physiological measures in their XR experiences. First, there can be considerable noise in the data, especially EEG measures of brain electrical activation (Ramirez and Vamvakousis, 2012). Moreover, wearing physiological sensors might feel cumbersome to the user, which may distract from the desired user experience.

2.5.2.3 Output

Change in object appearance/animation was by far the most common type of output (N=18), compared to change in music/audio (N=14), change in light/colour (N=11), object movement (N=10), user movement (N=10), and levitation/floating (N=4). Changes in music/audio and changes in object appearance/animation were more likely to be matched with respiration and relaxation or calm, whereas object and user movement were more likely to be matched with engagement and clarity. These outputs are in keeping with the literature: breath meditation can lead to relaxation and calmness (Carter and Carter III, 2016), and physical activities can bring about engagement and positive health outcomes (Gao et al., 2015). The current state of the XR technology is primarily focused on visuals, so it is not surprising to find most experiences using this in their interactivity. Audio and music are also easily modified through speakers and headphones. One observation is that some of the other human senses are underutilized, such as smell, touch and temperature. Some experiences make use of tangibles (Angelini et al., 2015; Roo et al., 2016; Sakamoto et al., 2015), but there is still a lot of work to be done in going outside visuals and audio for XR interactivity. In terms of well-being, emotion and memory are closely linked with the olfaction; odors that evoke positive autobiographical memories have the potential to increase positive emotions, decrease negative mood states, disrupt cravings, and reduce physiological indices of stress, including systemic markers of inflammation (Herz, 2016).

2.5.2.4 Outcome

Finally, the outcomes of using respiration rate as an input were relaxation, calmness, increased well-being, and decreased stress/anxiety. From these results, it appears that the main mechanism for eliciting positive states is through using biofeedback that is mapped to some kind of change in sensation in the XR environment, whether that be a change in music/audio, light/colour, or object appearance/animation; this feedback of physiological performance then allows users to experience an internal state from a different perspective and thus start to form the ability to change that state. It appears that practicing an awareness and control of one's internal physiological states can lead to positive states such as relaxation, calmness, harmony/balance, clarity, focus and increased well-being. From this mapping we saw that the outcomes were calmness, contentment/happiness, presence/embodiment, and engagement. Thus, the physical and virtual movement connection

seems to have contributed to eliciting positive states. And, when we look at the interaction strategies employed for these systems, we see play and movement are important. This is, the sense of curiosity, imagination, and embodiment in these experiences are all common themes and elements that allow the user to explore a system in a more natural and familiar way than a more abstract way of interacting like the traditional joystick. This idea of natural interaction supporting the desired user experience of curiosity, imagination, and embodiment in XR is maintained by several studies (Beckhaus et al., 2005; Desai et al., 2016; Macaranas et al., 2015; Quesnel and Riecke, 2017).

2.5.3 A Framework for Immersive Interactive Technologies for Positive Change

Several frameworks have already been proposed for designing technologies for eliciting positive human functioning and well-being: Anthropology-Based Computing (Brown, 2013); Techno-spiritual Design (Buie, 2016); Positive Computing (Calvo and Peters, 2014; Sander, 2011); Positive Design (Desmet and Pohlmeyer, 2013); Persuasive Technology (Fogg, 1999); Computer-mediated Self-transcendence (Gaggioli et al., 2016); Technowellness (Kennedy, 2014); Transcendence Technology (Mossbridge, 2016); User-centered Design (Norman and Draper, 1986); Positive Technology (Riva et al., 2012); Calm Technology (Weiser and Brown, 1996); Affective Computing (Picard, 2010); Ergonomics (Edholm and Murrel, 1973; Jastrzebouski, 2000); Hedonomics (Helander, 2002); Value-Sensitive Design (Friedman and Kahn Jr, 1992); Emotional Design (Norman, 2004) – see also Figure 2.1. However, these frameworks do not focus on immersive, interactive technologies (XR) in particular. Therefore, we offer a more focused and concrete framework for designing immersive, interactive technologies for eliciting positive states and supporting positive change (see Figure 2.6). This framework is constructed from the results of this scoping review: the interaction strategies and design elements, the input-output modalities that incorporate the use of XR technology, and the outcomes that resulted from the user's interaction with the system.

The designer or researcher has positive state(s) or positive change in mind as the outcome (orange). These outcomes will influence the theories and models considered when designing the experience (purple). Those theories in turn will help to inform the interaction strategies and design elements used (green). And, the interaction and design elements will then inform the feedback loop of input (blue) and output (red) modalities. Therefore, when the user is put into the system, their inner state is measured and collected via physiological measures and movement data. These data of the user's inner states are then fed into the system and represented/externalized in an abstracted way as the output modality. The user then experiences their own inner state that can change their initial state is then fed back into the system. Thus, the system and the user influence one another. This feedback loop over time can build positive experiences and contribute to a positive state. Eventually, this feedback loop shapes positive states, which then might lead to positive change in the user.

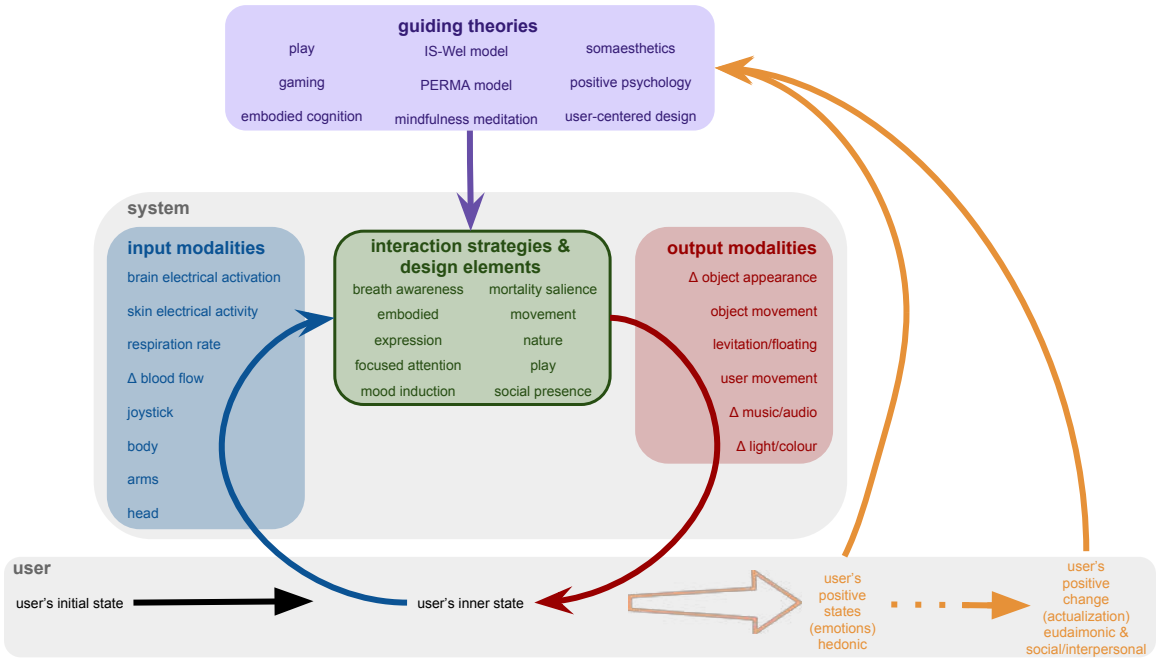

Figure 2.6: A schematic of the framework for designing immersive, interactive experiences for eliciting positive states and supporting positive change.

2.5.4 Design Considerations for Future Immersive Interactive Technologies for Positive Change

In addition to the themes listed and discussed above, which might be useful as descriptive tools for researchers, we now present a set of design considerations to serve as tools for designers and developers interested in creating immersive, interactive systems and experiences with the goal of eliciting positive states and supporting positive change. We want to note, however, that no formula exists to make someone have a given experience. We can only submit our best practices for giving the user suitable conditions and opportunities for them to engage if they wish.

1. **Consider the Outcome and Human Experience First, then Work Backwards**

   The intention or goal behind your work will shape every design decision, so it is important to have a clear sense of what specific positive state or positive change you wish to support with the XR technology. Trying to force the user to accommodate a technology that is not in keeping with their natural way of interacting and experiencing the world, even if it is a virtual one, can lead to frustration, negative emotions, and disconnect; this is in keeping with user-centered design and the existing frameworks for supporting positive functioning through technology (Calvo and Peters, 2014; Fogg, 1999; Norman and Draper, 1986; Riva et al., 2012).

2. **Consider Using Sensory Changes to Support Relaxation, Contentment, and Harmony/Balance**

   Our results of the scoping review for the input-output modalities (RQ2) suggest that specific changes in either music/audio, object appearance/animation, or light/colour can be associated with outcomes of relaxation, contentment, and harmony. These positive states are more subdued in feeling; therefore, the changes in the virtual environment too are subtle yet obvious enough to the user that there is in fact a change occurring. Hinterberger (2011) uses changes in light and sound to achieve all three of these positive states, while both Shaw et al. (2007) and Gromala et al. (2015) use changing imagery of jellyfish and fog, respectfully, to support relaxation. These sounds, animations, and colours used in the XR experiences all seem to support their desired outcome in some way, whether that be red colours for engagement, soft music with a low tempo or a setting sun for relaxation.

3. **Consider Using Movement to Support Calmness, Clarity, and Focus**

   Results showed that movement of any kind, i.e., user movement and object movement, was linked to positive states of calmness, clarity, and focus. More specifically, big sweeping physical movements of the user, and expanding/contracting of virtual objects in rhythm with the user's input helped to support positive states of calmness, clarity, and focus. This result is perhaps due to a release of bodily tension and stress, though more research is needed. These positive states are more active than the ones mentioned above because the user is physically engaged in the experience. Bal (2013) ORGONA project serves as a good example of using physical movement to support these three positive states because the user engages their body and focuses on their breathing to move virtual objects. Another good example is Muñoz et al. (2016) EmoCat Rescue game where users must focus on controlling their breathing and heart rate in order to progress in the game.

4. **Consider Using Biofeedback for Mediating Changes to the Virtual Environment**

   From the review, we found that physiological data was most commonly mapped directly to changes in the system, whether that be changes in music/audio, light/colour, or object appearance/animation. Users reported feedback that allows them to externalize and notice their internal states in the virtual environment helped them to better understand their own internal states, and maybe even gain more control of them (Patibanda et al., 2017; Vidyarthi, 2012). Our finding is supported by other research that shows biofeedback is effective in interactive technologies aimed at improving mindfulness – for a review see (Sliwinski et al., 2017). Moreover, the design considerations from Patibanda et al. (2017) provide positive evidence for using respiration rate as a

form of biofeedback in games: use subtle onboarding, use non-interruptive breathing feedback, provide imitative breathing feedback, use a minimalist approach to designing naturalistic visuals, and use hardware that considers breathing performance and increases self-awareness of breathing. Other forms of biofeedback we found in the review include blood flow changes, skin electrical activity, and brain electrical activation. While there are less examples of concrete experiences for these biofeedback elements, we can still observe that the majority of mappings for both blood flow changes and skin electrical activity are to more subtle changes in music/audio and light/colour, whereas brain electrical activation is primarily mapped to more obvious changes in object appearance/animation and levitation/floating. One reason for this might be that it is less obvious to the user when their brain state is changing rather than a change in heart rate or sweating, which we can physically feel or see more directly. Therefore, we suggest using a reverse proportional mapping – the harder it is to notice a physiological change, the more obvious the feedback should be in the virtual environment, and vice versa.

5. **Consider Mapping Physical and Virtual Movement Together**

   We observed that the use of physical movement and controller interaction strategies were most often mapped to corresponding virtual object or user movement. The use of physical movement in a virtual environment is important because it allows the user to feel more immersed in the experience. One study examined how users experience movements in their interaction with interactive systems and identified four features of movement-based interaction that potentially influence immersion: natural control, mimicry of movements, proprioceptive feedback, and physical challenge (Pasch et al., 2009). The models of immersion in this study were based off of two theories: Csikszentmihalyi (1990) Flow theory, a state of optimal experience where people typically have deep enjoyment, creativity, and total involvement in life; and Brown and Cairns (2004) immersion framework of engagement, engrossment, and total immersion. Thus, physical movement and locomotion in immersive interactive experiences might help support positive states and change, especially if we are to follow the guidelines mentioned above put forth by Pasch et al. (2009), as well as maintain immersion and user experience.

6. **Consider Natural Elements, Minimalist Design, and Child-like Play for Design Elements and Interaction Strategies**

   Many theoretical papers have already proposed using natural elements, minimalist design, and child-like play in interaction design (Ahn et al., 2016; Capaldi et al., 2015; Gaggioli et al., 2016; Schultz and Tabanico, 2007; Vidyarthi and Riecke, 2014). And, indeed, we found this to be true in the experiences we reviewed. Several studies we reviewed also found that using nature elements in the virtual environment (N=15),

taking minimalist approach (N=7), and adopting a child-like play concept for interaction design (N=16) all contributed to positive states or positive change in users – see results section for details on the specific studies. The use of abstract imagery in particular for taking a minimalist approach seemed to help users focus their attention and block out any external distractions; this abstract imagery also helps users to focus on something that does not come with preconceived ideas or feelings that may trigger an unwanted emotional response.

7. **Consider the Type of Technology Last Based on Your Desired Goals and User Experience**

   Finally, the type of technology used should be the last thing a designer should consider for their XR experience if they are to be in keeping with the principles of user-centered design. More explicitly, the technology or platform selected should support and enhance the desired user experience and outcomes. The goal should not be to use a certain technology simply because it is "cutting edge". We are seeing more and more XR technologies emerging, and that is promising for the field. However, the authors caution XR designers to think through why they are using a certain technology, and might another technology be a better fit? It should be clear how the XR technology elicits positive states and supports positive change, as well as how the extra effort of using XR technology is justified. The experiences we have seen so far, from this review, show that many are using virtual reality and in particular head-mounted displays. While this platform is great for total immersion, there still exist other forms of XR that might be equally or more beneficial; more research and development of experiences for other XR types is needed.

2.5.5 Limitations

The diverse nature of the various XR experiences and their accompanying studies presented challenges, leading to a series of compromises and assumptions that could be perceived as limitations in the literature review. First, an XR experience can integrate two or more interaction strategies and input-output modalities to support positive change. For example, pulse, brain potential shifts, and skin conductance can all influence the virtual environment's visuals and audio in different ways (Hinterberger, 2011). These kinds of integrations include a dominant outcome. In this review, the XR components were analyzed based on their dominant outcomes. For example, in the example above the outcomes were contentment, relaxation, happiness, and harmony. However, the distinction of what elements contributed to which specific outcome could not be determined from this review and so were considered together.

A second limitation is the vast differences in using empirical methods in all the studies identified for this review. Several of the studies included were only proof of concept (Bernal

and Maes, 2017; Choo and May, 2014; Du Plessis, 2017; Muñoz et al., 2016; Sakamoto et al., 2015)); therefore we cannot determine for sure that these interaction techniques will reliably elicit those same outcomes. Another limitation is in the generalizability of the reported outcomes because many studies used university students as participants. It is unclear whether the same outcomes will hold for the general population or more vulnerable populations.

Finally, the database query of the review is based on a predefined set of search terms. The defined search strategy conforms to the established procedures for scoping literature reviews, breaking down and addressing the research questions while ensuring reproducibility of the search. Yet, XR is a dynamic and vast field covering many different research fields; all of these fields have different terminologies and search terms that make it challenging to uncover every XR work that relates to positive states and change. For related reviews on neighbouring topics see these works: Capaldi et al. (2015); Mossbridge (2016); Plaza et al. (2013); Sliwinski et al. (2017); Spanakis et al. (2016); Valmaggia et al. (2016). Future scoping or systematic reviews on the topic might include the following terms, which are based on the key terms from the included literature in this review: virtuality, cinematic reality, computer-mediated reality, alternate reality, wearable computing, visuo-haptic mixed reality, games for health, HCI for peace, value-sensitive design, biofeedback, emotional design, holistic health, mediated communication, physiological computing, interactive art, multisensory experience, self-expression, prosocial behaviour, cultural worldview, narrative exercises, mood-induction procedures, and self-regulation.

2.6 Conclusions

We presented a scoping literature review of existing immersive, interactive technologies whose primary aim is to elicit positive states or support positive functioning. We discovered several ways to most effectively employ different design elements and interaction strategies to support positive change in users, as well as how to use input-output modalities to contribute to eliciting positive states. From this review, we formed a conceptual framework that may help researchers and designers think about immersive, interactive experiences in the context of positive states and positive change. In order to put forth a more concrete strategy for designers and creators to use this knowledge, we also provided a set of design considerations that also build on existing literature. The work presented here provides both researches and designers with a more organized and coherent sense of the existing literature on the subject across multiple fields.

Future work might address empirical evidence of how immersive, interactive experiences can elicit positive states or support positive change as this was something we found lacking in the literature. Another potential gap for designers to address is the creation of immer-

sive, interactive experiences for social/inter personal outcomes, opposed to hedonic and eudaimonic outcomes that we found to be a lot more prevalent.

2.7 Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

2.8 Author Contributions

AK, MP and BER contributed conception and planning of the scoping review; AK and MP formulated the inclusion/exclusion criteria and identified articles relevant to the topic; AK performed the screening and eligibility process, and conducted a qualitative research synthesis of the data; AK wrote the first draft of the manuscript; All authors contributed to manuscript revision, read and approved the submitted version.

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Chapter 3

Can Lucid Dreaming Research Guide Self-Transcendent Experience Design in Virtual Reality?

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3.1 Abstract

As virtual reality designers, we aim to create technological experiences to better human connection and well-being in hopes of helping humankind and society in a positive way. It is therefore important to ground the frameworks we use in genuine human experience rather than mindlessly apply models that do not account for highly personal and profound experiences. One type of experience that could help create positive connection and decrease self-saliency is self-transcendence. However, currently there does not exist a concrete model for designing self-transcendent experiences for virtual reality. Lucid dreaming, being conscious one is dreaming while in the dream, has the potential to induce self-transcendence; it is essentially the ultimate virtual reality. If lucid dreaming and virtual reality are so similar, then can we research self-transcendent experiences in lucid dreaming and apply that knowledge to virtual reality? In this paper we argue that lucid dreaming could indeed act as a guide for designing transcendent experiences in virtual reality.

3.2 Introduction

Technology is becoming increasingly prevalent in our everyday lives, making connecting with others easier and accessing information almost instantaneous. Yet, despite all these benefits that come with an increased presence of technology we still see its darker side: social networks are mainly shallow interactions, and many people are mindlessly consuming and sharing content. Consequently, decreased connectedness and increased self-saliency have ensued, which can lead to depression, anxiety, and decreased self-worth (Williams and Galliher, 2006). That said, there exist movements in different fields to design and use technology to support positive human functioning and well-being, e.g., Positive Computing and Positive Technology, which we will later elaborate on. One sub-field is Transcendence Technology, which aims "to design technology that facilitates three aspects of transcendence: moving beyond the self, connecting with others, and sharing pro-social goals and ideas" (Mossbridge, 2016). Therefore, we might be able to apply the design principles from these fields in order to create technologies that connect people in ways that are meaningful and authentic. However, the nature of transcendent experiences is highly personal and introspective in nature, and often cannot be described by the confines of language alone (Rankin, 2008). One existing technology that fits well with the experience of transcendence is virtual reality (VR) because of three unique kinds of transformative potentials: manipulating bodily self-consciousness, embodying another person's subjective experience, and altering laws of logic and nature (Gaggioli, 2016). Yet, there are currently no existing principles to guide the design of transcendent experiences in virtual reality. The authors believe the philosophy of user-centered design in this case should be upheld – designers should optimize a product around how users can, want, or need to use the product rather than forcing users to change their behaviour to accommodate the product that is not optimized for them (Norman and Draper, 1986). Thus, we posit that improving our understanding of real human experiences of self-transcendence might help us to design better virtual reality experiences that aim to provide a similar experience of transcendence. And, we have a particular transcendent experience in mind to guide the design of transcendent experiences in virtual reality: lucid dreaming – knowing one is dreaming while in a dream (LaBerge, 2009). Lucid dreaming may be a good candidate for several reasons, including its parallelism to virtual reality experiences and ability to induce self-transcendent experiences. We will elaborate on these points in the discussion.

3.3 Background

In the field of human-computer interaction (HCI), Norman and Draper (1986) first put forth the philosophy of user-centered design in an effort to put the needs of people at the center of product design rather than having technologists and designers force users to change their behaviours to match their products. From user-centered design came many

fields that attempted to integrate this philosophy: somaesthetics, technowellness, techno-spiritual design, positive technology, positive computing, and transcendence technology. In the following sections, we will provide a brief background on these fields before jointly discussing their contribution in the discussion section.

3.3.1 Positive Psychology, Technology, and Computing

Positive Psychology was developed by Seligman and Csikszentmihalyi (2000) in order to create balance, in opposition of the predominantly disease and treatment focused fields of psychotherapy and psychiatry, toward a model of human flourishing. From the idea of Positive Psychology came the fields of Positive Technology (Riva et al., 2012) and Computing (Gaggioli et al., 2017; Sander, 2011). Positive Technology was created from a psychology and social science perspective, focused on improving personal experience. Positive Computing, on the other hand, was created from a computer science perspective, focused on universal well-being design. Though each offer a different perspective on designing for positive technological experience, both Positive Technology and Computing attempt to integrate scientific principles of well-being into the design of interactive systems (Gaggioli et al., 2017).

3.3.2 Somaesthetics

Somaesthetics is the notion that all of our experiences and interactions in the world happen through our bodies, and that by becoming more aware of our bodily interactions we can also become more perceptive of the world we live in (Shusterman, 2012). The HCI literature has began to incorporate this idea into design practice and technological creation (Aslan et al., 2016; Fdili Alaoui et al., 2015; Höök et al., 2015; Lee et al., 2014; Schiphorst, 2009).

3.3.3 Technowellness and Techno-Spiritual Design

TechnoWellness is defined as "a mode of interacting with technology that maximizes its potential to enhance health and well-being and contribute to an optimal life" (Kennedy, 2014). TechnoWellness shares similar goals to Positive Technology, but Kennedy argues Positive Technology fails to incorporate some components of the counselling well-being models. TechnoWellness, then, incorporates the Indivisible Self (IS-Wel) model (Myers and Sweeney, 2005) that includes five second-order factors: Creative Self, Coping Self, Social Self, Essential Self, and Physical Self. Techno-spiritual design bridges the domains of spiritual experience and user experience (UX) by studying the artefacts in spiritual experiences (Buie, 2016). Techno-spiritual design uses a research through design approach combined with gaming to capture and create ineffable experiences such as transcendent experiences; the idea behind this being that people can express ineffable experiences through creativity. Unlike the previous domains of well-being and technology, techno-spiritual design does not refer to or build off of other theories.

3.3.4 Virtual Reality

Virtual Reality (VR) is an immersive space in which a user can interact with the environment. The first head-mounted display, called the Telesphere Mask, was invented in the 1960s by Heilig (1960) and then further developed into Headsight by Comeau (1961). Since then, we have witnessed more and more applications, but only now are designers and technologists looking at using VR beyond entertainment and training tools and into the realm for self-actualizing experiences (Botella et al., 2012). For example, there have been several VR experiences that aim to better mental health and well-being through meditative practices and biofeedback (Alcañiz et al., 2003; Amores et al., 2016; Bal, 2013; Baños et al., 2013; Bernal and Maes, 2017; Chittaro and Zangrando, 2010; Choo and May, 2014; Downey, 2015; Du Plessis, 2017; Karamnejad et al., 2013; Kosunen et al., 2016; Muñoz et al., 2016; Navarro-Haro et al., 2017; Patibanda et al., 2017; Prpa et al., 2015; Shaw et al., 2007).

3.3.5 Lucid Dreaming

Lucid dreaming is defined as the experience of knowing one is dreaming while one is dreaming (LaBerge, 2009). It has been described throughout human history, and was scientifically validated by LaBerge relatively recently through an experiment involving asking proficient lucid dreamers to move their eyes in a specific way when they were lucid while dreaming (LaBerge, 1990). The practice of lucid dreaming is related to Dream Yoga, a Buddhist practice of exploring one's consciousness during sleep (Holecek, 2016). However, lucid dreaming is not associated with religious practice. Instead, lucid dreamers can choose to interact or change their environment as they see fit, which may include interacting with or exploring their own consciousness (Stumbrys and Erlacher, 2017).

3.4 Discussion

There have been several fields advancing virtual reality applications relating to positive mental health and well-being, such as technowellness, techno-spiritual design, positive technology, and positive computing. Yet, the actual VR experiences created are primarily focused on stress reduction and modulating high valence emotional states, i.e., the hedonic level of positive human functioning, and less on self-transcendence, i.e., the eudaimonic and social level of positive human functioning. Currently, we do not have a clear model for designing self-transcendent experiences in VR. However, the advancement of somaesthetics, human-centered design, and transcendence technology point towards using genuine, real human experiences to help guide human-computer interaction. In the following sections, we will provide evidence for the claim that researching lucid dream experiences and practices might provide us with guidelines for designing better transcendent experiences in virtual reality, as well as address any counter-claims.

3.4.1 Lucid Dreaming as a Virtual World

Lucid dreaming has many parallels to virtual reality, which can make it a suitable subject to study for designing similar VR experiences. For example, lucid dreamers feel present in the dream world and can interact with the objects in it (LaBerge, 2000), which is similar to how users interact in a virtual environment. Lucid dreamers can also see fantastical worlds and experience things they would not otherwise be able to do in the real world, such as flying or conversing with a unicorn (LaBerge and Rheingold, 1990); this is much like virtual reality in that the virtual world is only limited to the designer's imagination and available hardware. Lucid dreaming is also much like VR because what is experienced in the lucid dream has real world effects both on a person's psychological and behavioural level (Voss et al., 2009). For example, one can change the outcome of a nightmare or practice a sport while lucid dreaming, and have that confidence carry over into waking life (Taitz, 2014). VR may have the same potential in modifying our behaviours and perceptions by allowing its users to feel as if the virtual world is really happening to them.

3.4.2 Transcendence in Lucid Dreams

Lucid dreams might be a platform in which to help induce transcendent experiences. Lucid dreams are created and informed by our own consciousness, which may give us a different perspective on our own internal states and thoughts (Voss et al., 2009). This altered perspective could give the right conditions that make transcendent experiences possible. There have been many reports from lucid dreamers that they use lucid dreaming as a way to introspect (LaBerge and Rheingold, 1990) and some researchers have argued that lucid dreaming presents a unique opportunity to study aspects of consciousness and introspection (Voss, 2010). Therefore, we can research lucid dreaming and we might use it as a lens into the unseen world of transcendent experiences.

3.4.3 Limitations of Lucid Dreaming Research

Lucid dreams may have many similarities to virtual reality and have the potential to induce transcendent experiences that we might then apply to VR transcendent experience design. However, there are several considerations and limitations we need to address. First, there is currently no empirically method to validate lucid dreaming experiences; we cannot look into the minds of lucid dreamers and see what they are seeing while dreaming. There is some research using EEG and fMRI to study sleep and dreams (Dresler et al., 2012). However, brain activity is quite different than subjective experience and even more different than capturing a self-transcendent experience. Therefore, any guidelines we might draw from lucid dreaming experiences of transcendence will be a second-hand account and may be flawed or biased. Yet, there do exist methods that can place the participant in the experience

as it happened to provide a realistic and accurate account, such as micro-phenomenology (Petitmengin, 2006) and cued-recall debrief (Bentley et al., 2005).

A second limitation for using lucid dreaming to provide insight into VR transcendence design is that current technology does not exist to capture the highly personal nature of lucid dreams. Hence, lucid dreaming cannot be fully realized as a VR experience.

However, the authors believe that technology will only get better at simulating these kinds of experiences reported in lucid dreams, e.g., flying, and that brain-computer interfaces will eventually be able to provide biofeedback to a VR environment based on the user's neurological states. Moreover, lucid dreaming could show the path towards what "natural" and intuitive interaction design looks like in VR. Even if currently we cannot totally simulate lucid dreaming experiences, we can still attempt to provide the space that allows people the opportunity to have a transcendent experience. After all, one cannot make a person have a transcendent experience – we can only design the right tools and environment in which a person might engage in one.

3.5 Conclusion

Spiritual experiences like lucid dreaming can provide us with rich data on how to better design for self-transcendent experiences in virtual reality because of their strong parallels to each other and potential for self-transcendent experiences. Lucid dreaming offers designers a unique perspective to both see how the ultimate VR might look at its full potential and inspire a product that is grounded in genuine human experience. With support from the fields of somaesthetics, technowellness, techno-spiritual design, positive technology, and positive computing, we might be able to design a virtual reality in which people could have self-transcendent experiences. Ultimately, these self-transcendent experiences in VR could have positive effects on people by increasing their sense of connection and decreasing self-saliency.

3.6 Author Contributions

AK wrote the first full draft of the manuscript; BR reviewed and provided feedback on the draft. Both authors read and approved the submitted version.

Chapter 4

Are You Dreaming? Designing for Introspective Experiences in Virtual Reality through a Phenomenological Study on Lucid Dreaming Practices

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4.1 Abstract

Virtual reality (VR) is resurging in popularity with the advancement of low-cost hardware and more realistic graphics. How might this technology help others? That is, to increase mental well-being? The ultimate VR might look like lucid dreaming, the phenomenon of knowing one is dreaming while in the dream. Lucid dreaming can be used as an introspective tool and, ultimately, increase mental well-being. What these introspective experiences are like for lucid dreamers might be key in determining specific design guidelines for future creation of a technological tool used for helping people examine their own thoughts and emotions. This study describes nine active and proficient lucid dreamers' representations of their introspective experiences gained through phenomenological interviews. Four major themes emerged: sensations and feelings, actions and practices, influences on experience, and meaning making. This knowledge can help design a VR system that is grounded in genuine experience and preserving the human condition.

4.2 Introduction

Technology is becoming more and more ingrained in our every day lives, yet it is only recently that HCI researchers, technologists and designers have paused to think about how these technologies could be used to better our lives and increase our well-being (Botella et al., 2017; Gaggioli et al., 2017; Roo et al., 2016; Valmaggia et al., 2016). While many mobile applications designed for this purpose exist (Mossbridge, 2016), one area that is still largely unexplored is virtual reality (VR). VR offers a low-cost and high quality simulation of environments and situations, which could be a powerful way to generate positive change in a non-threatening way because users can explore and play out situations they normally would not be able to do in real life. VR is unique in that it can completely immerse its users, that is provide the psychological experience of being completely absorbed in a physical or mental activity such that one loses sense of time and the outside world (Jennett et al., 2008). Immersion has been shown to increase presence, the physical feeling of being in the simulated environment, which in turn enhances the effectiveness of the experience (Cummings and Bailenson, 2016; Diemer et al., 2015; Riva et al., 2007). However, the question remains how to design for an effective VR experience that can elicit positive mental well-being? There exists a real life phenomenon that takes people into a simulated world that feels completely real and might generate a sense of positive well-being: lucid dreaming. Lucid dreaming is defined as knowing one is dreaming while in the dream (LaBerge, 1990). Once lucid, lucid dreamers have the ability to explore, shape, or create the environment as they see fit. Lucid dreaming, it seems, is the ultimate virtual reality in this respect because the lucid dreaming experience is only limited to one's imagination. As far as these authors could find, there does not appear to be any literature that focuses on lucid dreaming experiences specifically to inform the design of virtual reality experiences. We conducted a phenomenological study of nine active and proficient lucid dreamers. We interviewed the lucid dreamers about their experiences of lucid dreaming particularly focusing on lucid dreams involving introspection in order to answer the following research questions:

Main question: What are people's experiences of introspection in lucid dreaming?
Sub-questions:

1. What images, sounds, and other sensory stimuli are present during moments of introspection in lucid dreaming?

2. What are their relationships to the "feeling tone" and intensity of the emotional stimuli?

3. How might these experiences inform the design of an immersive virtual reality introspective experience?

From these interviews, we drew four major themes that could inform the design of an immersive virtual reality experience involving introspection: sensations and feelings, actions and practices, influences on experience, and meaning making.

There are two main contributions of this work:

1. Design considerations for introspective virtual reality experiences;
2. Interviews with proficient lucid dreamers that ground technological systems in a human experience.

4.3 Related Work

The work presented in this paper intersects multiple fields: it builds on positive technologies, focusing on virtual reality, and incorporates the real-life phenomenon of lucid dreaming in the context of introspective practices. These fields are briefly presented below.

4.3.1 Positive Technologies

There has been a recent importance put upon deigning for increased mental health and well-being in the HCI community (Gaggioli et al., 2017), with new research areas evolving such as *Positive Technology* (Botella et al., 2017; Riva et al., 2012) and *Positive Computing* (Calvo and Peters, 2014, 2015). Currently, there exists several overlapping well-being tech movements among designs and technologists, which Mossbridge (2016) has summarized in a review of Transcendence Technology. One focus of this research is on user experience (UX) and recognizing the importance of considering the human condition when designing for technologies (Gaggioli et al., 2017). That is, how can we design technologies that actively support well-being and human potential? In this study, we seek to ground design recommendations in real human experience through phenomenological interviewing of a very personal "virtual" world of lucid dreams.

4.3.2 Virtual Reality

Virtual reality is defined as the "model of reality with which a human can interact, getting information from the model by ordinary human sense such as sight, sound, and touch and/or controlling the model using ordinary human actions such as position and/or motion of body parts or voice" (Hale and Stanney, 2014; Hearne, 1978; Hobson, 2002; Holecek, 2016; Ihde, 2012). It has existed for decades, though it is only recently that the latest generation of head-mounted displays (HMDs) have become more affordable and accessible to the general public. Moreover, VR has the unique capacity to completely immerse its users in any environment, a component closely linked to presence or the feeling of being in the virtual space. Presence has been deemed central to a VR experience, often used as a "gold standard" or having validity. Some researchers have argued that presence is an important goal in transferring

VR application data to the "real world" (Mestre and Vercher, 2011). VR could act as a medium through which people can increase their mental well-being if there exist high levels of presence (Freeman et al., 2017).

Already, VR has been used for therapeutic purposes, such as PTSD treatment (Rothbaum et al., 2010), anxiety treatment (Opriş et al., 2012; Parsons and Rizzo, 2008), and pain management (Gerry, 2017; Tong et al., 2014; Wiederhold and Wiederhold, 2007). Moreover, VR has been used in a variety of stress-reduction and meditation or mindfulness-like applications (Roo et al., 2017; Shaw et al., 2011; Vidyarthi, 2012). It is clear that there is potential for VR to support well-being. However, the way in which designers and technologists create these experiences while keeping the human condition intact remains an open question.

4.3.3 Lucid Dreaming

Lucid dreaming, "dreaming while knowing one is dreaming" (LaBerge, 2014), is one phenomenon that we can draw parallels to a VR experience. It is a genuine human experience that places a person in a "virtual" reality, i.e., their dream, which feels in many ways as real as their waking reality. At the same time, lucid dreamers are aware that they are in a dream and that nothing in the dream has real-life consequences, much like that of a VR experience. Some researchers have dismissed the validity of lucid dreams, stating there was no evidence lucid dreams were distinct from rapid-eye movement (REM) sleep (Malcolm, 1956). However, several behavioural studies have since provided evidence that lucid dreams were possible (Hearne, 1978; LaBerge, 1990, 2000; LaBerge et al., 1986). More recently, technological advances have allowed researchers to record lucid dreaming with EEG, EMG, EOG, and fMRI (Dresler et al., 2012).

Psychophysical studies (Dresler et al., 2012; Mestre and Vercher, 2011) support the view that what people experience during REM sleep and lucid dreaming is the same as if actually experiencing it during waking life. This means that lucid dreaming could be used as a therapeutic tool because one can essentially do anything within the limits of their imagination, and that experience will have similar effects as if one experienced it in waking life. The parallels of lucid dreaming and VR are uncanny; by learning what enables lucid dreamers to have such powerful introspective experiences, we might also learn some valuable guidelines for recreating similar experiences in VR.

4.3.4 Introspection

One way lucid dreaming, and thus VR, could be used as a therapeutic tool is for introspection – the examination or observation of one's own mental and emotional processes (Byrne, 2005). Introspection can provide privileged access to our own mental states – including sensory, bodily, cognitive, and emotional – that are not mediated by other sources of knowledge, so that one's experience of the mind is unique; and this can be beneficial in a clinical and

general sense (Kohut, 1982). Moreover, introspection can increase the quality and quantity of information people have about themselves and break down the barrier of the ego that affects how people process information about themselves (Carlson, 2013). Many dreamers report that they use lucid dreaming for introspection, such as dealing with psychological issues or spiritual growth (Schädlich and Erlacher, 2012). And, researchers have suggested that applications of lucid dreaming could include nightmare reduction, treating depression, and rehabilitation (Taitz, 2014). However, learning the techniques of lucid dreaming takes time and discipline, and one may not even experience a lucid dream until a month into keeping a dream journal, setting an intention each night to lucid dream, and doing reality checks–such as checking how many fingers you have sporadically throughout the day (LaBerge, 2009). Additionally, many people still feel skepticism towards lucid dreaming because of dream report inaccuracy (Malcolm, 1956) and its ties to spirituality. One could potentially induce lucid dreaming through frontal low current stimulation of gamma activity. A research group stimulated a certain area of the brain with transcranial alternating current and it was effective 70% of the time in giving naïve participants lucid dreams (Voss et al., 2014) However, the mere induction of lucid dreams ignores the many benefits that surround the practice of lucid dreams and the ultimate goal of being present or aware of your surroundings and ego in waking life (LaBerge, 2009). Approachable ways to introduce the concepts of introspection are important in generating true and genuine experiences with technology so that we can keep the human condition and experience intact.

We propose investigating the experiences of introspection in lucid dreaming so that we can inform the design of an immersive technological system (VR) that can be used as a tool for introspection in order to help people explore or understand their internal states, ultimately creating a more positive sense of mental well-being.

4.4 Study Methodology

The goal of this phenomenological study was to describe the essence of what it is like to introspect in lucid dreams. The experiences gleaned from describing what it is like to introspect in lucid dreams and its context could be useful for designing a similar experience in the format of an immersive technological system in virtual reality.

4.4.1 Participants

We interviewed nine participants who are currently active and proficient lucid dreamers. LaBerge (2014) recommends the following when selecting lucid dreamers as participants:

1. verify that informants understand the concept of lucid dreaming by requiring the inclusion of a recognition phrase in a sample lucid dream report and

2. use highly trained participants who are skilful and accurate observers of their conscious experiences.

In an entrance survey, we determined that the average time participants have been actively lucid dreaming is 20 years, and the average frequency of lucid dreams is 1 per week. Participants (6F, 3M) were the age of majority where the research was conducted, with an average age of 35 years (19-57 years range). We posted online advertisements on social media groups (e.g., Facebook and Twitter) and lucid dreaming forums. Participants for this study were naïve to this study and did not have prior relationships to us in order to decrease any potential power imbalances and increase the validity of their reports.

4.4.2 Research Site

The interview took place in a quiet and undisturbed place, where there were little distractions and the participant could focus on the interview. The interview was in a neutral location as to not create an imbalance of power between the researcher and the participant. If possible, the interview was conducted at a place where the participant was comfortable and relaxed, in order to create an environment that allowed them to open up about their experience. Some interviews were conducted over online video conferencing for the participant's convenience.

4.4.3 Data Collection

From a quantitative perspective, researchers are concerned with discovering facts about the phenomenon and assume a fixed and measurable reality. However, the nature of dreams, especially the content of dreams, is dynamic and a negotiated reality; this is much better suited to qualitative methods, which are more concerned with understanding human behaviour from the informant's perspective and does not assume a fixed reality (Creswell, 2012; Moustakas, 1994). It is very difficult to conduct research relating to dream content for a variety of reasons, most notably is that we cannot watch dreams while they are happening and the dreamer cannot report them while the dreams are happening. Therefore, there is no way to have objective evidence concerning the content of the dreams. Some quantitative researchers have used neuroimaging techniques, such as EEG and fMRI, to study which areas of the brain are active during dreams (Dresler et al., 2012; Hobson, 2002; Voss et al., 2009). However, one could argue that this is fundamentally different than collecting data on what the dreamer actually perceives. Most dream researchers believe the best way to study dreams is through content analysis of dream reports, which can be from sleep laboratories, psychotherapy relationships, personal dream journal, and anonymous reports (Domhoff, 2000). In order to gain a rich understanding of the phenomenon, this research needs to emphasize the context in which introspection in lucid dreaming occurred and the meanings of these lucid dreams for participants.

Using qualitative methods to study lucid dreams and their experiences with introspection, we intended to discover from the participants what kinds of sensations, feelings, and experiences they had during introspective lucid dreams, as well as the setting and conditions that lead to their experiences. Fallman argues for a philosophy of technology in HCI, building on Ihde's phenomenology of relations between humans, artifacts and the world, and Borgmann's suggestion to rethink the relationship and correspondence between "useful" and "good" technology (Fallman, 2007, 2011). In this same line of argument, we sought to give a new lens in which to provide guidance concerning how to incorporate specific values, namely introspection, in designing VR experiences. Phenomenology in particular has direct relevance to design (Gallagher, 2013); several researchers have shown how phenomenology has been and can be used both as a theoretical stance and as a research approach (Cilesiz, 2011; Dourish, 2004; Ihde, 2012; Webster-Wright, 2010). We used semi-structured interviews that lasted 25 minutes to one hour in order to discover what participants have experienced in terms of introspection in lucid dreaming and what contexts or situations have typically influenced or affected these experiences. This phenomenological interview consisted of three main domains: contextualization (natural attitude and life world), apprehending the phenomenon (modes of appearing, natural attitude), and clarifying the phenomenon (imaginative variation and meaning) (Bevan, 2014).

Interviews were audio recorded using the "Voice Recorder" app on a Samsung Galaxy S6 smartphone or Quicktime built-in audio recorder in order to be as unobtrusive as possible. It is important that the tone and feeling of the participants' experiences also be taken into account when analyzing the data due to the very personal nature of the phenomenon. We wrote a reflection and debrief after each interview in order to capture any behaviours, tone, feeling, or impressions from the interview. Video recording could also serve the same purpose, though it is unclear if a visual component will add anything to the data and, given the personal nature of the study, a camera can feel more intrusive. Audio recordings of the interview and interview's notes were imported into NVivo 11 for Mac, a qualitative data analysis software, and transcribed to text.

All interviews were kept anonymous. Contact information was stored on the university's server. The university's Institutional Review Board approved this study, and the participants signed informed consent forms. A demographic questionnaire was administered online using Fluidsurveys and was completed before the interview.

4.4.4 Data Analysis Methods

The method of analysing phenomenological data mentioned in Creswell's Qualitative Inquiry and Research Design book (Creswell, 2012) was used for this study, which is essentially a synthesis of Moustakas' and Giorgi's "psychological phenomenology" (Giorgi, 1985; Moustakas, 1994). Here, we identified the main categories or meaning units and composed a textural description to capture what the experience of introspecting while lucid dream-

ing is like for participants, a structural description of the phenomenon, and a description capturing the essence of the phenomenon. Finally, we used these descriptions to inform design recommendations for introspective experiences in virtual reality. Quotes are followed by P#, where # denotes the participant's ID.

4.5 Results

From nine verbatim transcripts, four main categories or themes emerged across participants: sensations and feelings, actions and practices, influences on experience, and meaning making. Next, we will discuss our findings for each of these four main themes where we will highlight key insights.

4.5.1 Sensations and Feelings

Experiences of bodily sensations were prevalent in lucid dreams relating to introspection. These senses mapped closely to what participants had experienced in waking life, such as touch, smell, taste, sound, vision, and sense of space. There was a sense of clarity and heightened awareness of the environment when participants became lucid in their dreams. Lucid dreams were described as visually vivid, intense, bright, and graphic. One participant even likened their dreams as better than Avatar, a film renowned for its cutting edge visual effects and psychedelic qualities:

> It's better than Avatar... the thing I love about it the most is that it's just I get to see the environment that I love. So, really rich, thick kelp forests with sea dragons and cuttle fish and octopus, fishing, glowing neon lights. –P8

Visuals seemed to be the primary sense in which participants experienced their lucid dreams, and even without any other sense present they still felt like they were immersed in the dream. In terms of other senses, lucid dreamers could smell, taste, and touch as if their dreams were real. There was a sense of complete immersion in the dream and at the same time lucid dreamers knew it was not actually real. In fact, even though there were many inconsistencies in the lucid dream, such as flying without wind, sound without a source or hands with too many fingers, this did not deter participants from accepting those inconsistencies and still having the feeling of presence as if in the real world. There too were senses that could not be explained in terms of our everyday experiences, or rather our language could not account for such an experience that is outside the realm of anything we have experienced before:

> ...you don't use your senses in your dreams. You have an impression of what the senses are like. Like a really distorted thing is vision; you can get into it, you can get lucid and you look out and you see something... so that the sense are, uh, I suppose the only way we know the world now. So, in a lot of dream states

> are the only way you can reference it. You want to see this and touch that and taste that and feel it. –P1

Though some sensations cannot be described, the sensation around transitioning into the lucid dream straight from a waking state was described in detail by P9. They were able to witness and remember the transition into sleep with all the bodily sensations that come with that experience. Here they describe imagining being on a boat in the sea and remaining conscious of their bodily state while at the same time transitioning into this other world:

> In those 20-30 seconds... I could actually I started to hear the waves crashing on the boat and it just became more and more clear and I could sort of feel the boat moving in the sea and I could start to see all the mountains appear, but it was weird because I also felt my body on the couch, so it was like I was between two worlds. And slowly, as time passed... I could feel the vibrations, I sort of feel myself on the couch but it was just drifting away and my awareness started shifting into the boat and before I knew it, in maybe a minute or two, I was in the sea. Like it was clear as day. It was like the real world but I was actually just sitting on my couch. –P9

The feeling of realness and presence existed even with knowing they were still actually on their couch. Visuals and vibrations were not immediately thrown at this participant, but rather there was a build up and an easing into the dream space. This way of transitioning was so powerful for the participant that they felt in awe of the experience once they were in the lucid dream. Their imagination had come to life before their eyes.

In terms of emotions and affective states, many participants reported positive feelings of bliss, happiness, freedom, peace, lightness, and childlike-wonder and playfulness. This is particularly prevalent in lucid dreaming experiences of flying. In fact, almost all participants reported that they often flew in their lucid dreams because it was a fun experience, something they could not do in real life, and provided a means of letting go of any frustrations or worries:

> I also have these feelings of intense happiness and bliss and peacefulness and also exhilaration. I love flying and I love being out of control in my environment." –P8

Flying brought about feelings of both peace and excitement, perhaps from the flowing feeling from physically gliding through the air paired with the exhilaration of a superhuman like experience. These lucid dreamers liked to push the boundaries of what is possible and, in doing so, could experience something otherworldly; that experience was so powerful that it could have a positive influence on lucid dreamer's affective state. Another feeling lucid dreamers seem to experience often was a sense of control over everything, omnipotence, empowerment, and limitlessness. Participants reported that they could move objects with their mind and that feeling of control gave them a sense of power:

> I just wake up going like I'm omnipotent! I love the telekinesis because it just feels so effortless as well. –P7

Because lucid dreamers could control and manipulate the dream environment with their will, they could create or mould the experience to their liking, which was very empowering. The experiences that lucid dreamers tended toward were often magical or living out a fantasy, whatever that may be. For one participant, this meant going to a grocery store and gorging on their favourite foods or foods they would normally restrict in real life:

> I can eat whatever I want. I went to the freezer section because I wanted a freezer cake, not like a regular cake but a whole thing of freezer cake. And then, someone had bought a calzone but then didn't want to eat it so it was like in front of me. So, I ate a whole calzone. I ate mac and cheese. There's always mac and cheese at Whole Foods. When I was eating a bunch of stuff and I woke up and I was like that was so exciting, like that's something I wish I could do; everything's free in Whole Foods and the carbs don't affect my blood sugar and whatever. So, I had a field day. –P2

From this account we can see that lucid dreams were a way for them to experience something they would not normally be able to in real life, which may sometimes be due to physical restrictions. Moreover, any experience in a lucid dream does not have real world physical consequences, such as caloric intake, falling from a great height, or swimming with whales. Lucid dreams provide a safe and private space for people to explore different sensations and feelings without fear of judgment, and this allows them to really let go and find a sense of peace and state of non-suffering.

4.5.2 Actions and Practices

Participants reported acting within their lucid dreams by exploring, creating, playing, problem solving, and interacting with dream objects and characters. Exploring often involved nature, such as rocketing into outer space or swimming with dolphins:

> I think for me especially the ocean it speaks volumes to me for reasons I've spent a lot of time in and around the ocean and exploring it as a child. And I love it. I mean, to start off, I'm an ecologist, so I love the environment. I love nature and I explore the terrestrial environment all the time, but the ocean is one that I can't really get to in my waking life. –P8

Lucid dreamers could manipulate the dream space so that they could explore facets of the world unknown or unreachable to them. But it was not only physical spaces that lucid dreams could explore; they could also explore the nature of their own minds. One participant, P9, recounted a lucid dream in which they attempted to push the limits of

what was possible in a lucid dream by counting down from ten in order to "go deeper" in the lucid dream. What they found was a dream scene of greater perceived "realness". The "realness" of the dream within a dream seemed to truly stay with this participant because, as they explained, it felt like a deeper level of being. Going even deeper, this participant found themselves in a dream scene of blood, gore, and violence, which they interpreted as going deeper into sub consciousness to the more primitive parts of human nature. It appears that exploring both physical and conceptual spaces is a large part of the experience of lucid dreaming for these participants.

Some participants would also create in a lucid dream. For example, one participant described walking through a gallery in their lucid dream and seeing all these beautiful paintings they could not have possibly created themselves, but in actuality it was their own mind that created them:

> I can't paint. I can't paint whatever, hopeless. But, there was a period of time when in my dreams when I said, you know, I want to go into a gallery and I want to see paintings in that gallery. I want them to be abstract. I want them to be beautiful... So, I wander through this gallery and I see all these paintings. I'm sure if I could have painted them, I'd be probably one of the most successful painters on the planet, but they're absolutely incredible. My mind has put them together for me; they didn't exist until I saw them in the gallery and asked for them to be there when I went and saw it. –P1

It is incredible what the mind is capable of when we test its limits and are in a space where we believe anything is possible, such as in a lucid dream. One could be the next Picasso or Cezanne if they were given the space to explore and create without the limitations and impositions commonly placed on them in real life. There was a magical quality to being in the lucid dream space, where the lucid dreamer was aware that it is all a dream and at the same time still received the psychological benefits as if having actually done or experienced those things in the dream.

A lucid dream also provided the space for problem solving or taking action in the dream to change it into a more positive experience. For a few participants, it was common to have nightmares. But rather than become frightened, they became lucid and realized they could take control of the situation to either escape or make it into a less frightening scene. There was a confrontation with the dream space itself, and a conscious decision to change their own mind into a more positive state:

> I think it was a couple years ago it was a zombie dream. I was watching a lot of Walking Dead, so it started off as a nightmare and then it became kind of fun. I realized that I could hover above it and I wasn't in danger and I could kind of watch it as if it was happening – like sometimes the dreams turn into kind

> of like I'm watching a movie or something. It's entertaining and I don't want to wake up. –P4

What participants do or how they interact in their lucid dreams showed that they had some agency and sense of control that was both empowering and fun. Lucid dreams were a playful space to explore and experiment within the safe confines of one's own mind. And, it was not only the contents of the lucid dream that seemed to be important, but also the practices surrounding lucid dreams. Almost all of the participants reported some sort of practice in attempting to increase their lucidity. This included more systematic and scientific approaches such as reality checks, continuously questioning the nature of reality in real life in hopes that when you were in the dream space you would do the same and realize you were dreaming, taking supplements, keeping a dream journal, and tracking bodily states. Reality checks were important to establishing lucidity for participants because it was one way of being certain they were dreaming, e.g., plugging your nose and attempting to breathe (P2). There were more spiritual and ceremonial approaches as well, including lighting incense, opening oneself to the experience and letting go of the ego through meditation or yoga, and focusing on the breath through mindfulness practices. Many of these practices, mentioned by participants, have been demonstrated to help achieve lucidity in the literature (Gackenbach and LaBerge, 2012; LaBerge, 2009). Whichever method of helping to induce lucid dreams, it is clear that there was some preparation or ceremony surrounding the practice. One participant spoke to the importance of ceremony going into a lucid dream:

> I think ceremony is probably most specific because it [lucid dreaming] doesn't mean anything if you're not using it for a certain reason, right? So... getting into the state of ceremony because I think ceremony teaches us how, and that's I guess probably even with technology, like even just turning on, having to make your bed or something like that, having time to lay down, having cushions, be comfortable, all sorts of ceremony, right? So, those states of taking the time to do this, to get ready, so that we are ready and we can get into the state. [Ceremony] just tells your mind, like I'm getting into the state now, something different, it's not the regular; pay attention and allow our spirit to show up. –P6

Setting an intension and focusing attention seem to have a profound impact on the level of lucidity, and ultimately the outcome of the lucid dreaming experience. It is rare that a lucid dream will occur at all if one is not creating a habit or ritual around it, much less the fanciful awe-inspiring ones experienced by the most dedicated and experienced lucid dreamer.

4.5.3 Influences on Experience

4.5.3.1 Self-awareness and Focused Attention

Lucid dreaming and the practices surrounding it have commonalities with other introspective methods, and often participants would be using these other introspective methods in tandem with lucid dreaming. A common practice reported amongst participants was meditation:

> 10-15 meditations that are like a body scan or deep relaxation type of thing, that's like you know, relax your head, relax your shoulders, doing that type of thing... I tried one... Bilateral stimulation. So, that's what this is called, it's like a ticking or beat that alternates between your ears and its supposed tone, it's used as a treatment for people with, who have experienced trauma, like helps people work through or heal trauma or something... I felt more aware of my dream and I don't know if it's linked to that or because I thought it would impact them or something. I don't know if it did. But, I could remember specifically, the morning dream that I had after listening to that meditation, I felt more aware of it. –P5

Being aware of the present moment and focusing on the body is the most commonly reported type of meditation amongst these lucid dreamers. The practice of lucid dreaming was about being aware of reality – what was real and what was not – in order to gain lucidity and control over what was happening in the dream space. So, these two practices compliment each other: both attempting to achieve greater awareness of what was happening in the environment and the self. One participant even mentioned a practice called Dream Yoga – an extension of lucid dreaming only more of a spiritual practice, founded in Buddhism, where one studies the mind using the medium of dreams [30]. Lucid dreaming, on the other hand, does not have as many spiritually oriented methods and, thus, might appeal to a wider audience. One type of meditation P5 mentioned is bilateral stimulation, which could involve listening to tones that alternate between the left and right sides of the head, and is reported to decrease physiological arousal and increase attentional flexibility [13]. Decreased arousal and increased attention could be linked to this participant's lucidity in dreams, though they profess to not be sure if this was a placebo effect or not.

4.5.3.2 Negotiating with Reality

Other experiences that seemed to be linked to participants' lucid dreams, but were distinct experiences, were the following: out of body experiences (OBEs), astral projections, and false awakenings. OBEs are defined as perceiving the self outside one's body, often from a distance and are involuntary. Astral projections are like OBEs, except they are voluntary. Finally, false awakenings are vivid and convincing dreams that feel as if one has awoken,

yet the dreamer is unaware they are still dreaming. This is in contrast to lucid dreaming where dreamers are aware they are dreaming while in the dream. All of these experiences seemed to be either extensions or side effects of lucid dreaming practices. That is, when one plays with perception and consciousness in lucid dreaming practices, sometimes the mind can turn that around and give the impression of leaving one's body or that one is awake when still dreaming. Furthermore, when one is an experienced lucid dreamer, they can push the boundaries of the dream further and do things like go out of their own (dream) body:

> There's a point where you can become body-less, you can extend beyond yourself, you can lose your concept of self, you can dig deeper... There's a place which I call the void and you go in a dream, and go from one dream to another through a mirror into another one. And you get into what I call a pillar state where you'll have, as if it's a whole lack of imagery but it's a lot deeper. I say your watching thought before it's formed up into anything, just raw thought. –P1

4.5.3.3 Setting an Intention

In addition to these related practices to lucid dreaming, these participants would often use psychology treatments or conditions to enhance or make sense of their lucid dreams. One practice, already previously mentioned by P9, was to count down from ten, similar to hypnosis – a state of consciousness where a person is more suggestible. P2 explicitly said they used hypnosis as a way to "hack your thoughts, to make yourself think how you want to think in order to increase your confidence or feel better". These practices of introspection, like hypnosis, seemed to help with lucid dreaming because of an ability to be in a more suggestible space and suspend disbelief in order to experience or accomplish the impossible. Cognitive behavioural therapy (CBT) was another psychological treatment mentioned by a participant that complemented lucid dreaming in its ability to look at a situation or thought more logically:

> It was like the breaking down of the disillusions in CBT and looking at things more logically, [that] kind of felt like how I dealt with my dreams. You know, when you're not lucid everything is an illusion and you're not in reality until you think about it logically. You realize... everything is a figment of my imagination. –P2

4.5.3.4 Gaining Control

They were able to use the techniques from CBT to bring about a sense of clarity and heightened awareness in their lucid dreams, and in doing so had a much richer and meaningful experience. In terms of psychological conditions, one participant likened lucid dreaming to psychosis – a mental condition characterized by losing contact with external reality:

> You're in this state where you can't, like with psychosis, see reality and you can't snap out of it. But then that rational part of your mind can be reasoned with a bit. So, I've tried to be like [this], you know when you're dreaming and you can suddenly realize you can control it. –P4

P4 was describing the struggle of becoming lucid in a dream, where they were fighting their own mind to take control of the dream space. They equated this struggle to psychosis because their sibling experiences psychosis sometimes and perhaps it was a way for them to relate to and understand that condition, but also a way to conceptualize what lucid dreaming was like – namely, it was partly a negotiation for control and knowing what was real.

All of these experiences were separate from lucid dreaming, but were nonetheless both related to and had an influence on lucid dreams. In understanding these influences, we can begin to determine what enhances the experience, what are the prerequisites, and what are its limitations. From the accounts of these nine participants, it seems like focused attention and self-awareness both help to enhance lucid dreams. Setting an intention, negotiating with reality, and gaining control appear to be integral aspects of lucid dreaming. Finally, lucid dreaming can be used to experience your wildest fantasies, it can be used to rehearse situations, or solve problems. However, it is limited in its ability to go deep and connect with the most inner aspects of being; for that you have meditation, dream yoga, or astral projecting.

4.5.3.5 Meaning Making

Though lucid dreams cannot reach the deepest and most secret parts of being, they can still bring about authentic experiences and meaning. It was the case for all participants that they experienced some sort of introspective experience, shift or change in perception, connection to self or others, or self-growth from lucid dreaming. Lucid dreaming for some participants could be a way to gain access to sub consciousness because their waking body was asleep. P3 described interacting with dream characters where they would ask these dream characters who they were and what they represented to them in the dream. Often, there would be no answer or the character would represent an internal conflict or aspect of the self. Other participants reported interactions with dream characters as well. P2 told a story about a lucid dream where they confronted a dream character about why they felt sad and received a response that they felt was a reflection on their own state of being; and the act of acknowledging those feelings actually helped them to feel better:

> I asked her what she felt bad about, and she said inferiority. I said what would make you feel inferior? She said other people. I asked her if she didn't feel inferior when she was alone? She kind of fell over sad and didn't answer. The whole thing made me sad especially because why would this person who's a movie star feel

> bad or inferior to other people? I felt like crying a few times. So, I guess [this was] someone who I think is really great but at the same time they feel inferior. And... I think it's like the part of me that feels like it struggles between feeling really good and feeling really bad about myself. –P2

These dream characters did not only have to be human either. P8 talked about communicating and making friends with animals in their lucid dream. Speaking with these animals was a way for this participant to connect on a deeper level, "as if speaking to their best friend"; in doing so might create a sense of positive well-being. Another participant, P6, also experienced animals as dream characters. However, in this case, it was not so much about being able to connect in a different way as in the previous example, but more an allegory for their mother's passing:

> My mom was sick so I had her dog for a while. And I had lucid dreams that this beautiful lady was kissing me and it would mean that my dog would have to go pee. I saw this lady that I encountered that was very beautiful and she was wrapped in chains and she was saying let me go [P6], let me go... And I watched her cross the street, she got hit by a car, her guts were like all wrapped around her... it took me a little while [to know what] that vision was about here because I forgot that I see her [the mother] as that lady who I had been seeing, not the dog. I feel like she was telling me to let her go, but I think I held on a little bit longer. –P6

Interacting with dream characters was one apparent and bold way of seeking meaning in a lucid dream. Another was for one to use lucid dreaming as training grounds in order to build confidence in the real world. This could take the form of confronting a fear or escaping a nightmare. P4 and P7 both had lucid dreams with zombies, but were able to apprehend the scary situation by recognizing it as a dream and laughing at it or flying away. P7 would use lucid dreams as a way to practice sports like snowboarding and try out different moves to gain confidence to do them in the real world. This practice worked because the lucid dreaming space felt so real, so it felt like they were there doing it. Another way to gain confidence was to do something in the lucid dream that one would not think was possible or that one had never done before; and through that experience, one could learn and grow, carrying that feeling of accomplishment over to the real world:

> I was sitting on this concrete thing in my kayak [attempting to get] over into the far pond and I had to jump. And I was like I don't know if I can do this. But then I just gave myself confidence and just kind of breathed with it and I managed to do this strange kind of jump. And it was such a moment that sat with me for like the whole next day... because I was like it's just that confidence, confidence to do it, you know, and actually hold that feeling. –P7

Even though the dream space was not happening in reality, and the participant was aware of this fact in the dream, the experience still had an effect on their confidence long after waking. And, for a few of the participants in this study, it was a very powerful and overwhelmingly positive effect. They had the ability to take the dream for what it was, even with all its inconsistencies and bizarreness, and make what they could from it. Sometimes, though, diving into the depths of one's mind revealed some fairly surprising and frightening aspects. A few participants ventured to go into the deeper parts of their mind. P1 described a dream space that they called "the field", which was an electrical field of energy that sent dreadful, terrible sensations down their spine. P2 was in a lucid dream and wanted to meditate, which to them meant getting rid of the entire external environment and focusing on themselves. However, this proved to be a very intense experience because it felt too black, too isolating, and too quiet. To be completely alone with the self is not really something most of us experience, and so when P2 encountered that it was too much to handle at the time. P9 also experienced a very intense lucid dream where they wanted to go deeper into their mind, like the dream within a dream idea popularized by the movie Inception:

> All around me was a lot of blood and gore and violence... my theory was that because I went a lot deeper into the subconscious it was sort of like I saw more primal parts of human nature and that was all the blood, gore and violence. –P9

Lucid dreams were a chance for the lucid dreamer to actively search out experiences and draw meaning from them. These dreams could be symbolic or carry meaning depending on if one wants them to or not. Some of the participants were not interested in finding a meaning or purpose, but would rather have fun or be entertained. Others were very interested in figuring out what the feeling in the dream represented or find answers to unlocking life's secrets. P5 acknowledged this difference of intent for lucid dreamers, reflecting that people's own dreams can mean something, not like a black cat means bad luck, but that dreams are very personalized and we can draw meaning from them if we wish or choose to say it means nothing at all. The point was that people make meaning, they choose to see something in a seemingly random and strange world of dreams. And, that is not nonsense; that is a real feeling that lucid dreamers take with them into real life.

4.6 Discussion

The accounts of introspection described by lucid dreamers are consistent with the descriptions of control, self-healing, and self-awareness in the literature (Gackenbach and LaBerge, 2012; LaBerge, 2009). Here, we have identified four themes that center on the essence of what it is like to introspect in lucid dreams: Sensations and Feelings in lucid dreams involved what the lucid dreamer perceived and felt physically during their lucid dreams, as well as what they felt emotionally during their lucid dreams; Actions and Practices where

ceremony was important surrounding the practices of lucid dreaming involving exploration, problem solving, discovery, and creation; Influences on Experience explained that many lucid dreamers had introspective practices and experiences such as meditation, connection to nature, and sense of curiosity that has helped them to gain greater awareness or agency in lucid dreams; and Meaning Making where lucid dreamers had the opportunity to go deep within themselves or analyse the content of their dreams to create their own meaning.

4.6.1 Essence Description

Lucid dreaming, according to the accounts of our participants, is knowing you are in a dream while dreaming, and then having the potential to take control of that dream and mould it to whatever fantasy, situation, feeling, or space one desires. In doing so, the lucid dreamer frees themselves from the laws and bounds of waking life, which feels "very tranquil, blissful". In terms of introspection in lucid dreams, there is a vividness and clarity that surrounds the experience; the lucid dreamer can do as they please in a safe environment without judgement or repercussions imposed in the real world. There is a chance to explore one's thoughts and feelings, and uncover "secret knowledge" known only to that individual. Lucid dreaming is different and very personal for everyone, and at the same time the essence of the phenomenon is common across each of the participants here. For most of the participants interviewed here, it could be a connection, a lens, and a way of communicating with the self.

4.6.2 Design Implications

There exist studies that have described the nature of lucid dreaming, but unique to this study is the specific focus on introspection, whereas prior studies investigated experiences of lucid dreaming in a broader sense (Gackenbach and LaBerge, 2012; LaBerge, 2009). Having participants provide detailed and rich descriptions of their experiences with introspection in lucid dreams provides data that can be utilized in generating design recommendations for a virtual reality system that helps people with introspection, with the ultimate goal of improving mental well-being.

4.6.3 Corroborated Results

The sensations and feelings of vividness and clarity generated through lucid dreaming practices could be applied to the context of VR, echoing prior work on VR recommendations. Our findings show that visuals are very important to the experience, especially ones that are vivid, because it immerses the user in the environment and ultimately creates the feeling of realness. Other senses such as sound, taste, touch, and smell all contribute to the experience, which is in keeping with previous research (Jerald, 2015). Yet, if any senses are missing or somehow different from those experienced in the real world, then that does not

diminish the experience because there is an acknowledgement that this environment is not real and so the same affordances and laws may not apply. One implication of this finding might be that the strong focus on graphical quality in VR is perhaps not as important as previously thought (Brooks, 1999; Riecke et al., 2005). Knowing that the environment is not real does not seem to be as important to the immersiveness of the experience itself. Moreover, accuracy of the environment does not seem to be necessary for the feeling of realness either. It is sufficient that there be awareness of the present environment. These findings are supported by previous work, proposing that a realistic experience is no longer immersive VR's sole goal (Bowman and McMahan, 2007).

In terms of what users might like to do in VR and how designers might approach introspection, the lessons from our lucid dreaming participants are to create experiences that give a sense of exploration and an open environment where there is the feeling of possibility. The experience should be fun, playful, and childlike in nature to encourage exploration and wonder. Designers should consider the medium of VR and think about what experiences people normally would not be able to do in the real world; this may look like something fantastical such as flying, as suggested by Mueller et al. (2007) and Sikström et al. (2015), or seeing another part of the world people would normally not have access to. Our reports from lucid dreamers indicate that some people may wish to interact and change things in the environment and others may not. In any case, users should feel like they are in control of these interactions, which generates feelings of empowerment and confidence that can carry over into the real world. This benefit of bodily control was also found by Byrne et al. (2016).

From our results, we found that the transitions and experiences surrounding a VR experience are important in creating a safe environment, without judgement or repercussions imposed in the real world, for its uses to explore the unfamiliar. This finding is supported by Patibanda and colleagues' recommendation to "ease-in" users for VR (Patibanda et al., 2017; Sproll et al., 2013). Just as our bodies are gently eased into sleep and into a lucid dream as a seamless experience, so too should the transition into and out of VR. The user is aware that they are sitting on their living room couch or their office chair, but they are invited into another world where they must suspend their disbelief that this is all unreal and then be open to the possibilities that such a world might offer. To make this leap as easy as possible, as designers we might think about borrowing tools of introspection from other domains such as psychology, spirituality, and mindfulness. These introspective tools teach awareness, discipline, considering another perspective, loss of ego, and letting go of what we think we know is possible. If these aspects are incorporated into the design of introspective VR experiences, then positive and transformational outcomes like those seen from lucid dreaming might be possible. Therefore, when transitioning into VR, think about the surrounding environment – is there a seamless transition? Can the user feel safe enough to let down their guard and truly immerse them selves in the experience? When

transitioning out of VR, there is again the connection back to the real world that eases the user between worlds and allows space for reflection.

4.6.4 Nuanced Insights

Ceremony around an introspective experience in lucid dreaming helps to ease the transition into the dream space, so VR designers might also think about what ceremonies or preparations the users are undergoing in order to prepare for them for the virtual world. Ceremony seems to bring more meaning to the experience because the person going into it is more mentally and physically ready and open.

The space of the virtual environment itself might be quite abstract or feel empty and vast, like some lucid dreamers reported while they meditated in the dream. Nature is a theme in lucid dreaming and it also has close ties to human connection, so including those aspects can help in creating a sense of peace and awe. Furthermore, an abstract world gives space for the user to provide their personal meaning and interpretation, which is important in exploring one's thoughts and feelings or uncovering "secret knowledge" that is personalized to that individual. And, an environment where the user is bodiless can provide the right conditions for letting go of the ego, the outer sense of self and focusing inward.

These design considerations for introspective VR experiences taken from accounts of lucid dreaming are promising because they echo those considerations already put forth in the VR literature (Gaggioli et al., 2017; Jerald, 2015; Lotte et al., 2012; Mossbridge, 2016). However, these design considerations we have presented here have not yet been put into practice. Though VR and lucid dreaming have many commonalities of user experience, it may be the case that there are other factors at play that VR cannot account for in providing introspective experiences. For instance, VR experiences are under complete control of the designer whereas lucid dreams ebb and flow on the spot depending on the dreamer's mental state. So, until we have reliable brain computer interfaces combined with VR, then that is one limitation of the technology. Further research is required to test the validity of our design considerations and eventually put forth a more robust set of design guidelines for introspective experiences in virtual reality based on human experience. It is essential that this technology ground itself in genuine experience in order to preserve the human condition.

4.7 Conclusion

Virtual reality could be the platform that allows its users to explore introspection and have a positive impact on well-being because of its potential to provide an immersive space that feels real despite its user knowing it is not. A completely immersive VR experience draws may parallels to a real life "virtual" phenomenon people already experience, namely lucid dreaming. By using qualitative research methods to study introspection in lucid dreaming, we described the essence of this phenomenon as well as the context in which it occurs. The

descriptions generated were used to develop design considerations for an immersive virtual reality system that will be used as a tool for introspection. From preliminary findings, there are four themes: Sensations and Feelings, Actions and Practices, Influences on Experience, and Meaning Making. Overall, it seems like lucid dreaming can be used as an effective tool for introspection and can be helpful as a new lens in which to look through in designing for introspective virtual reality experiences.

4.8 Author Contributions

AK and TS contributed conception and planning of the phenomenological study; AK performed the interviews and conducted a qualitative research synthesis of the data with consultation from TS and BR; AK wrote the first full draft of the manuscript; All authors contributed to manuscript revision, read and approved the submitted version.

4.9 Acknowledgements

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Chapter 5

Designing Mind(set) and Setting for Profound Emotional Experiences in Virtual Reality

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5.1 Abstract

Virtual reality (VR) has the potential to support profound emotional experiences, such as experiencing awe when virtually viewing the Earth from space. In doing so, VR can potentially both give people positive emotional experiences contributing to their overall well-being and give researchers a way to study these profound emotional experiences in a more controlled environment. Through a design refinement process, we explored the potential

Figure 5.1: Five stages of the multisensory experience: into the lab, into VR, through VR, out of VR, and out of the lab. For more detail, please see this supplementary video: `https://youtu.be/SW6hNl3mgJw`

influence of the "set and setting"–one's mindset and the physical and social environment– when transitioning people into and out of VR designed to support profound emotional experiences. We present our findings from a design refinement session and a case study exploring how set and setting may support the profound emotional experience of awe. We discuss common themes in user experience and trends of awe-related measures. Our results contribute to the discourse around the role of the design of set and setting in overall user experience.

5.2 Introduction

Virtual Reality (VR) allows for realistic sensory simulations in which a person can perceive, feel, and interact in a way that is similar to real-world (Parsons et al., 2017) when they are exposed to a vivid illusion of reality (Rubio-Tamayo et al., 2017). One application of VR involves using it to induce experiences capable of leading to improvement of well-being and positive emotions (Kitson et al., 2018a; Yaden et al., 2018), which generally refer to the interconnected dimensions of physical, mental, and social health (Fredrickson, 2001; Seligman and Csikszentmihalyi, 2000). VR is especially useful in supporting specific types of profound positive emotions, such as wonder and awe (Chirico et al., 2017, 2018; Quesnel and Riecke, 2017), because these emotions are complex and embodied, hence need a suitable medium able to provide a multisensory embodied experience. The ability to use VR to support profound emotions provides new opportunities and also raises new questions for design research (Gaggioli et al., 2017). Most previous research in VR involved health care interventions, training simulations, and entertainment applications (Cipresso et al., 2018; Slater and Sanchez-Vives, 2016). However, a growing number of VR experiences is intented to induce specific positive emotional states in a controlled environment (Chirico et al., 2016; Yaden et al., 2018). These VR experiences can not only be used to put an individual in impossible or inaccessible situations, such as seeing the Earth from space (Quesnel et al., 2018), but also help researchers understand the specific manipulations that influence these profound experiences.

Using consumer grade VR headsets, e.g., HTC Vive, and custom software, e.g., Unity3D, helps make it feasible to design virtual environments (VE) that may enable people to experience profound positive emotions, and thus increase well-being (Bailenson, 2018; Riva et al., 2016). The potential benefit of increasing exposure to emotional experiences could affect millions of lives since there is a lot of evidence that well-being and positive human functioning are both correlates and outcomes of these experiences (see review (Yaden et al., 2017)). For example, one in four people worldwide are affected by mental or neurological disorders at some point in their lives that negatively affect their well-being (noa, 2001). Exposure to positive emotional experiences, such as spirituality and nature, is dwindling (Hassed, 2000). If we can provide people with an effective alternative to experience profound positive

emotions, then this may improve mental well-being for millions of people. The overarching research question for this design space is then:

(How) can we design VR experiences that are effective at supporting profound positive emotions? And, if so, what are the important design features of such experiences that contribute to promoting profound positive emotions?

Preliminary studies have begun to use VR for studying awe, one of several profound positive emotions, in lab settings (Chirico et al., 2017, 2018; Quesnel and Riecke, 2018; Stepanova et al., 2019a). Although we focus specifically on the positive qualities of awe in this study, awe is a complex emotion characterized by intense feelings of astonishment, wonder and connectedness that arises when one is confronted with something vast that transcends previous knowledge schemas (Keltner and Haidt, 2003). Studies have yet to reproduce intense feelings of awe, possibly because of the sterile lab conditions. Thus, there is an opportunity to shape user experience by designing the journey leading to profound emotional experiences from the moment the immersant, person immersed in VR, arrives at a space, where they will enter a VE, to the moment they leave that space. Here, the immersant is gradually transitioned to another reality rather than simply putting on an "immersive" headset and expecting to have this intense and profound experience. Already we have seen researchers studying the effects of gradual transitions in VR to increase presence (Jung et al., 2018; Knibbe et al., 2018; Smolentsev et al., 2017; Steinicke et al., 2009, 2010; Valkov and Flagge, 2017). Nonetheless, these studies have so far only focused on the visual transitions rather than the emotional and embodied transitions that are important to profound emotional experiences. Moreover, the space after the VR experience may be important for immersants to reflect and accommodate what they just experienced. There are few research-based design guidelines for the design space of VR-based profound emotional experiences and the set and setting surrounding it (Buie, 2016; Chirico et al., 2018).

Our goal is to provide design knowledge that can support other HCI researchers and designers to explore and contribute to experiences surrounding immersive technologies such as VR. First, we design a prototype of transition space in and out of VR and focus on the specific design elements that support our intended user experience in VR, in this case the feeling of awe. Second, we refine our design elements and improve user experience through a design refinement process inspired by future workshops and walk-throughs. We sketch and discuss the outcomes of the workshop. Third, we explore the potential of set and setting for supporting profound emotional experiences with our revised design in a case study by using semi-structured interviews and behavioural measures. A case study approach facilitates exploration of a phenomenon within its context using a variety of data sources. A case study is used because this topic is relatively new and needs exploration first, and we seek to capture the complexity and variability of participant responses before narrowing the scope of research in a more controlled study.

The intended goal of the virtual experience is to support a profound emotional experience of awe. Our research question for this study asks *how can gradual transitions into a VE support the experience of presence, a profound emotional experience, and correlates of awe, such as diminished perceived self-size, creativity, and pro-social behaviour*? Furthermore, *what design features are important in creating the set and setting for the virtual experience*? We present the findings of both our design workshops and case study, and discuss common user experience themes suggesting the promise of set and setting in supporting profound emotional experiences in VR. In the future, a more wide-scaled controlled experiment would enable us to make stronger claims about the effectiveness of set and setting. Our work makes the following contributions:

1. a research prototype and case study that explores transitional elements supporting the profound emotional experience in VR;

2. user experience themes for supporting profound emotional experiences in VR based on both our design workshops and case study results that through discussion can contribute to future development of design considerations.

5.3 Related Work

This project intersects multiple fields: it builds on theories of profound emotional experiences, incorporates positive technology, and is inspired by both non-media and media's use of ceremony and gradual transitions into and out of experience.

5.3.1 Profound Emotional Experiences

5.3.1.1 Defining Profound Emotional Experiences

Profound emotional experiences refer to a feeling of very great or abnormal intensity to an experience, often accompanied by a feeling of unity or ineffability (Stange and Taylor, 2008). Profound emotional experiences are congruent with the characteristics associated with mystical, peak, aesthetic, and self-transcendent experiences. Researchers have provided a vast amount of evidence that these varieties of profound emotional experiences are both correlated with and directly result in well-being and positive human functioning–see reviews (McCarthy et al., 2018; Smith and Liehr, 2014; Yaden et al., 2017). These well-being outcomes include mental and physical well-being, prosociality, self-management, and life quality and satisfaction (Botella et al., 2017; Garcia-Romeu et al., 2015; Wong, 2016). Yet, accessibility to these experiences is limited due to many factors, including decreasing exposure to both nature (Miller, 2005) and spirituality (Fuller et al., 2007) in parts of western society in recent years.

5.3.1.2 Technology and Profound Emotional Experiences

Technologies can provide novel opportunities to experience phenomena that might not otherwise be available, including profound emotional ones —see Mossbridge (Mossbridge, 2016) for a recent review. Immersive VR can enhance research of profound emotional experiences because it offers realistic simulations with a high degree of experimenter control; researchers can track behaviour and correlate it with the provided multisensory experience; it can be integrated into narrative contexts, supporting a sense of presence (Gorini et al., 2011); and VR can produce "impossible" situations to investigate research paradigms (Rosenberg et al., 2013), which can extend to better understanding so-called ineffable profound emotional experiences. Yet, we still do not know the full potential of using VR to support profound emotional experiences, or how to best design for such experiences. That is, what are its limits and challenges? Some researchers have proposed that combining immersive VR with gaming and narratives can possibly create novel and powerful ways to induce profound emotional experiences (Gaggioli et al., 2016).

Specific examples of VR supporting profound emotional experiences are sparse but show promise for future investigation. Immersive VR experiences of the Earth from space can elicit awe in people (Quesnel and Riecke, 2018; Stepanova et al., 2019a). Similarly, a virtual scene of high snow mountains, a forest, and the Earth can induce higher levels of awe and presence compared to a neutral VE (Chirico et al., 2018). Several meditation-inspired virtual experiences exist too. *DEEP* (Van Rooij et al., 2016), *Life Tree* (Patibanda et al., 2017), and *Pulse Breath Water* (Prpa et al., 2017) use breathing biofeedback to control virtual nature elements. Both *The Meditation Chamber* (Shaw et al., 2007) and *Inner Garden* (Roo et al., 2016) use forms of meditation to lower stress and promote self-reflection. These experiences all make use of immersive VR, which block out audio-visual distractions and help participants focus on the experience. Yet, simply putting a headset on someone and expecting them to have a profound emotional experience seems optimistic at best. It seems like there might be a better way to ease people into and out of VR in a way that better supports and aligns with profound emotional experiences.

5.3.2 Set and Setting

Most VR research so far has focused on the experience of being in VR and the effects after exiting, and little work has been done on the set and setting surrounding VR (Knibbe et al., 2018). The set (short for mindset) and setting (physical and social environment) might be important for both preparing for VR and giving space for reflection and accommodation after VR. Many forms of immersive media use transitions to support a particular mood or response, e.g., theme parks and theatres. The experience itself seems to be greatly influenced by the actions and thoughts that come directly before and after actually engaging with it. Therefore, designing for the set and setting might better support profound emotional experiences in VR.

5.3.2.1 Set and Setting in Everyday Life

In our everyday life we experience transitions, often in the form of ceremony or ritual, e.g., getting ready for the day or winding down after work. These rituals seem to prepare us mentally and physically for the intended activity, and not doing them can have negative consequences, for instance, not taking a bath before bed may lead to a bad sleep. These rituals are not only ingrained in our everyday lives, but also in contexts such as art galleries, spiritual or religious practices, and drug-induced altered states of consciousness. The key to supporting a profound emotional experience is by carefully considering the design of *set and setting* —a term first coined by Alfred Hubbard and later used by Timothy Leary and colleagues to describe the importance of the physical, mental, social, and environmental context one brings into a psychedelic experience (Leary et al., 1971). A recent study on the phenomenology of lucid dreaming, knowing one is dreaming while dreaming, supports the idea of ceremony as being integral for having introspective experiences (Kitson et al., 2018b). These non-media examples may be helpful in informing the design of profound emotional experiences in VR because the field is relatively new and there is little guidance on how to do so.

5.3.2.2 Set and Setting in Performance and Entertainment

We see set and setting in media all the time, such as going to the movies, theme parks, art installations, and black box theatre. The entertainment industry especially has exploited the fact that transitioning people into and out of media gradually and effectively helps to support and enhance the total experience, often leading to a more positive user experience and greater profit (Gelter, 2006). Theme parks, such as Disney, have used 3D projections to enhance the experience of attractions such as the *Haunted Mansion*, the *Tower of Terror*, *Snow White's Scary Adventures*, and *The Storytellers Sandbox* (Mine et al., 2012). Video games use foreshadowing and pre-experience narrative to spark curiosity and enhance perceived continuity (Scirea et al., 2014; Wouters et al., 2011). In immersive theatre, Punchdrunk spectators don masks before being set free in the performance space, allowing their inhibitions to fall away so that they can fully explore their surroundings and become totally absorbed in the world around them (Prudhon, 2018). Benford and colleague's (Benford et al., 2009) trajectories framework points to the importance of continuity through an experience. They have identified key transitions to consider to maintain continuity, most relevant to our project being *beginnings and endings* and *traversals between physical and digital worlds*. Beginnings must be designed to introduce narrative, build suspense, brief participants, and deal with practical concerns. Endings must be designed to encourage participants to re-engage with the experience, which can include ritual debriefings. For traversals between physical and digital worlds, one should embed the virtual technology within the space so that the virtual extends outwards. Moreover, participants should be physically separated

from potential distractions; and the use of doorways, curtains, or passageways can both physically and mentally transport the participant into and out of the virtual space. Set and setting in these existing performance and entertainment spaces could provide a rich insight into how they affect user experience in VR, particularly how set and setting affect the ability of VR to support profound emotional experiences. These frameworks and best practices guided our design, which we detail later.

5.3.2.3 Set and Setting in VR

Some of the earliest studies looking at designing VR set and setting come from Disney's VR Studio and Imagineering. In *Aladdin's Magic Carpet Ride*, they found that narrative before VR helped ease people into VR (Pausch et al., 1996). In *Pirates of the Caribbean*, interactive story structure helped satisfy a guest by dividing the experience into three phases: an introduction to learn the interactions, the main experience for players to explore, and an exiting conclusion to bring closure (Mine, 2003). Other researchers found improved awareness and perceived interactivity (Valkov and Flagge, 2017) as well as improved illusion of virtual body ownership and presence (Jung et al., 2018) when users are not directly "thrown" into an unknown virtual world but start their journey from a replica of the room which slowly morphs into the desired virtual world. Similarly, researchers found that gradually transitioning users from a virtual replica into the intended VE helps users perceive the VE as more real, supports perceptions of possibility to act, and levels of presence because the familiarity eases users into the novel experience (Smolentsev et al., 2017; Steinicke et al., 2009, 2010). Other researchers proposed using embodied transitions to both physically and perceptually ease the participant into VR (Sproll et al., 2013). Most recently, Knibbe and colleagues looked into the precise moment of exiting VR and found five components related to the experience: space, control, sociality, time, and sensory adaptation (Knibbe et al., 2018). The implications of the above work point toward set and setting of VR as a way to either heighten or lessen an experience. While prior work has looked at user experience in terms of reducing spatial disorientation and increasing productivity, we look toward how set and setting might heighten or lessen the more profound emotional experiences in VR.

5.4 Project Overview

We provide an overview of the AWE, Awe-inspiring Wellness Environment, project including the context and virtual environment. In the subsequent sections, we present the process in designing our research prototype of set and setting surrounding a VR, the design process for refining our design elements, and the case study. We present our design research process in the order it occurred. This research was approved by the local ethics review board.

5.4.1 Project Context

We used an existing non-commercial VR experience[1] —AWE (Quesnel et al., 2018). AWE is inspired by the overview effect, i.e., the profound experience that astronauts have, when seeing the Earth from space and feeling overcome with a sense of awe, wonder, oneness with the planet, and compassion for the environment (White, 1998; Yaden et al., 2016). AWE is staged in a lab setting, designed to help researchers study the overview effect and participants' potential reactions of awe. The AWE project makes use of a meditative-like physical mixed reality environment for privacy and emotional priming (Quesnel et al., 2018). However, the inclusion of a pre-VR experience was not something explicitly designed for nor formally studied or explored in detail in that paper. Moreover, researchers of the AWE project did not include a post-VR experience, which could be helpful in supporting accommodation of the profound emotional experience experienced in VR. We only used the VE part of AWE; we explicitly studied the set and setting surrounding the VR experience that would gradually transition the participant from the physical reality to the virtual, and back again, in order to amplify and better support a profound emotional experience. This process involved drawing on the literature as well as our own personal experiences. Each design decision needed to be justified and support the overall intended outcome —awe.

There were three project phases that overlapped (see Figure 5.2). The development team included two experienced VR researchers; senior graduate students; and a small team of digital media students. We worked closely through iterations of the design and development, including technical experiments, concept designs, and usability testing for two weeks prior to the design refinement session. We then iterated on the design following the design sessions to hone in on the most relevant and potentially fruitful design aspects.

5.4.2 Virtual Environment

The VE took the immersant on a journey through three stages. First, the experience started in a tent at a campsite, from where the immersant was lured to exit into the night forest by a magical creature —"Sprite" (an animated particle system). Second, the Sprite invited the immersant to follow it through the forest and then take a leap of faith into the lake where the immersant descended through the deep-water environment with fish and jellyfish. Third, the immersant transitioned into Space and followed the "Sprite" to the climax of the experience, where the Sun and Earth revealed themselves. After orbiting around the Earth, the immersant was brought back to the tent, where it was now daytime. Please see this paper(Quesnel et al., 2018) and video for a more detailed description of the VE: `https://vimeo.com/268130902`.

[1]We obtained permission from the original authors.

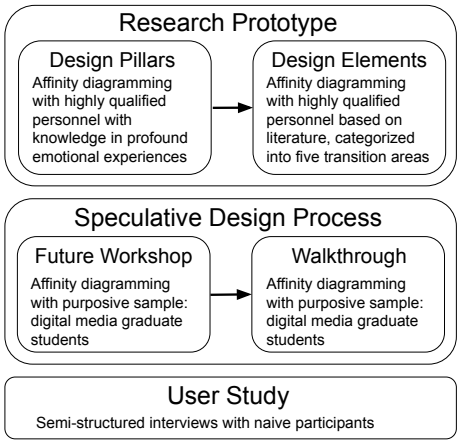

Figure 5.2: Design and evaluation process with three phases: (1) Research Prototype, (2) Design Refinement Process, and (3) Case Study.

5.4.3 Technical Apparatus and System

The AWE experience system was composed of the HTC Vive stereoscopic head-mounted display (HMD), which has 2160 x 1200 resolution, 90Hz refresh rate, and 110diagonal FOV. We used its Lighthouse laser tracking system, along with a portable desktop computer. Audio was through stereo sound, noise-cancelling headphones: Sennheiser HD 4.50 BTNC. Participants sat either on a modified stool that could rotate 360r an office swivel chair that had the wheels removed, and HMD cables were hung above to prevent entanglement.

5.5 Designing a Research Prototype

5.5.1 Design Pillars

We grounded our design elements in three "design pillars" —a game design concept that defines 3-5 elements or emotions the experience is trying to explore or make people feel (Pears, 2017). Design pillars are used in the games industry for brainstorming high-level, action-centric concepts or goals that act as development guidelines before the team begins working as a way to streamline the design process and create a focused, unique experience (Despain, 2013). Despain (Despain, 2013) states brainstorming is a common method used to generate pillars and three pillars are a common practice as it allows for depth without too much complexity; we chose affinity diagramming as a brainstorming method because the process not only generates ideas but also organizes and coheres them. Specifically, we brainstormed ideas relating to our overall goal of supporting awe and mental well-being in VR. Our group consisted of awe experts and we drew ideas from both the literature and our personal experiences. Within the affinity diagramming exercise, we agreed on three design pillars:

(1) Childlike Wonder: curiosity and exploration are fostered by an openness to the experience as it unfolds (Silvia et al., 2015);

(2) Perceived Agency: courage and confidence lead to empowered choices and actions that further the depth of the participant's exploration (Coyle et al., 2012);

(3) Self-transcendence: increase the participants sense of connectedness, oneness and prosocial attitudes and behaviours, as well as decrease self-saliency or ego (Stange and Taylor, 2008).

5.5.2 Design Elements

An affinity diagramming exercise was repeated for generating specific design elements for transitions that were grounded in literature while also keeping in mind our three design pillars above. We categorized the elements into five transition types based on participants' perceptual shift from one space to the next as described by Benford and colleagues (Benford et al., 2009) and Sproll and colleagues (Sproll et al., 2013): into the lab, into VR, through VR, out of VR, and out of the lab, as illustrated in Figure 7.1. Implicit in these transition types is continuity of narrative, which helped inform our design choices. Next, we describe each design element for these transitional types in terms of how they relate to our core **design pillars** (in bold) and their expected effect. *Design elements* (italicized) are presented as they are experienced in chronological order by the participant.

5.5.2.1 Transitioning into the Lab

Entering the space, the participant found themselves in a *dark room* with *forest* smells from a diffuser and sounds from a speaker. Sense of smell is strongly tied to memory (Willander and Larsson, 2006), so we speculated participants would conjure up images from their past camping trips and perhaps ignite **childlike wonder** since camping was a common childhood experience for members of the design team. Beside the entrance was a *costumes* trunk containing articles of nature-like quality: fur vest, cape, lei, feather boa, fur scarf, and an inflatable bee beard (see Figure 7.1: 1. Into the Lab). Dress-up can provide the opportunity for transformative play; by dressing up and taking on new roles, we learn more about ourselves (Fron et al., 2007). We expected the *costumes* to intrigue the participant and allow them to embody a new character in the spirit of playful curiosity and **childlike wonder**. Next, the guide handed a *lantern* to the participant, which provided the participant with **perceived agency** to light their path, explore their surroundings, and engage with curiosity about the forest-like environment. We expected the participant would feel an increased sense of trust and safety by using a *lantern* because it keeps the path lit in an unfamiliar space and can invoke a sense of part-taking in a new experience (Coyle et al., 2012; Mine, 2003).

5.5.2.2 Transition into VR

The participant walked down the dark hallway with the *lantern* and saw a projection of a *nighttime forest* with small fireflies, meant to "set the scene" and foreshadow the virtual

forest environment to come. Projections have been shown to enhance location-based experiences (Mine et al., 2012). The ground was also lain with black plastic to simulate the sound and feel of walking over leaves and the *forest floor*. A small, artificial *campfire*, a *camping chair*, and a *cooler* were at the end of the forest hallway. The participant sat in a *camping chair* with a mug of *hot chocolate* and a *s'more*, a traditional camping snack, often for children (see Figure 7.1: 2. Into VR). With all of these campfire design elements, we aimed to inspire **childlike wonder** through nostalgia and playfulness of wilderness camping. We anticipated the items were familiar and comforting to participants, which would feel soothing and safe at this point in an unfamiliar environment. Moreover, by layering familiar elements into unfamiliar junctures of the experience, we hoped the design elements also fostered the participant's sense of connection to the experience, perhaps opening them up to a **self-transcendent** experience. We used a simple narrative of a camping scene combined with physical props before VR since these can help transition people into VR (Mine, 2003; Pausch et al., 1996). On top of the cooler were three origami animals or *talismans* with a note (Figure 7.1: 2. Into VR). These *talismans* used an art-form that was **child-like**, and also provided a choice or **perceived agency** because participants had to select one, throw it into the fire, and yell out their choice. *Talismans* are often used in rituals or ceremonies because of their magical associations (Gonzalez-Wippler, 1991), and we expected participants to see these origami figures in the same way. After the talisman was voiced, the experimenter would then place the corresponding headset *mask*, i.e., owl, frog, or deer (see Figure 7.1: 2. Into VR). These *masks* were selected because of their nature-like qualities, which matched the theme of the experience; and because masks are used in rituals as a means of transgressing boundaries, which might relate to **self-transcendence** (Napier, 1986). The experimenter would then turn on a *blue light*, shifting attention to the VR *mask* and signaling to the participant that the VR experience was ready. The participant would then don the headset and go through the AWE virtual experience (Figure 7.1: 3. Through VR).

5.5.2.3 Transition out of VR

The end VR scene had the participant back in the tent they originally started except it was now daylight, suggesting it all might have been a dream. Upon taking off the headset, they were greeted with a similar change in scenery in the physical environment: a *daylight forest* projection, sounds of *birds chirping*, the *campfire* extinguished, and *"sunlight"* beaming down. These design elements supported the third design pillar of **self-transcendence** because the transition from night to day continued the sense of connectedness to nature and the transience of the moment. We expected the use of projections, sounds, and lighting would contribute to the experience by giving continuity and story structure (Mine, 2003; Mine et al., 2012; Pausch et al., 1996). On the *camping chair*, the participant found a *journal* to record their reflections (see Figure 7.1: 4. Out of VR). We wanted to give space

for thoughtful reflection in a playful way that afforded **perceived agency** and **childlike wonder**, and journaling can support transformative learning by helping people develop an understanding of connections between themselves and the world (Hubbs and Brand, 2005). We also left the self-image drawing task (explained below) next to the journal, which participants could complete at any time before rejoining the guide. This was playful and creative in itself, but also a reflection of how participants see themselves in the world —an opportunity to reflect on **self-transcendence**.

5.5.2.4 Transition out of the Lab

Once finished journaling, the participant had unrestricted time to reflect on their experience in the immersive installation, and could linger in the reflective state for as long as they needed and perhaps finish their *s'more* and *hot chocolate*. This time was designed to provide the space for reflection that would allow participants to accommodate the potentially profound experience they have gone through (Gaggioli et al., 2016; Mezirow, 1997). When the participant finally met back with the guide, they handed back the *lantern* and *costumes* before exiting together (Figure 7.1: 5. Out of the Lab).

5.6 Design Refinement Process

Our aim for the project's second phase was to refine our design elements to support the gradual transition into and out of the "AWE" project. We sought to bring in an outside perspective and generate creative solutions for transitioning people into and out of VR. To this end, we held a workshop with a walk-through of the experience to inform the use of transitional elements in our project. The focus here was on further developing and solidifying our design choices, whereas the next phases focus on exploring the user experience in depth through a case study.

5.6.1 Participants and Methods

We recruited a purposive sample of persons with VR experience in order to maximize our understanding of the perspectives of immersants, even though a randomized sample would have given greater external validity (Merriam, 1998). We invited seven graduate students from a digital media university to participate in a design workshop and walk-through of our experience. They were already very familiar with the AWE project but were naïve to the pre- and post-VR experience.

Designing for self-transcendence through technology, such as VR, is a complex design problem because the experience itself is ineffable and multiple factors such as prior experience, expectations, and mindset can greatly affect the outcome. To this end, we involved users in the design process itself because a more wide-ranging perspective fosters detailed understanding of the problem, gives room for diverse ideas, and may produce creative solutions (Scariot et al., 2012). For our design refinement process, we married two activities to

foster and communicate new concepts and ideas: future workshop and affinity diagramming. Future workshops are best known in participatory design, and proceeds in three stages: critiquing the present, envisioning the future, and implementing the new initiatives (Muller, 2003). To facilitate brainstorming, we used affinity diagramming —a commonly used method in Contextual Design and HCI to organize and make sense of qualitative data in four stages: creating notes, clustering notes, walking the wall, and documentation (Lucero, 2015).

5.6.2 Procedure

After signing the informed consent, participants received an oral description of the study, which included three stages: future workshop with an affinity diagramming exercise, walk-through of the immersive experience, and postmortem reflection. In the future workshop, participants first engaged in a brief discussion of the challenges facing transitions into and out of VR today. Second, they used affinity diagramming to envision what their "perfect", imagined transitions into and out of VR might look and feel like. We provided the same five categories we used in the first phase that participants could think about in terms of transitions in our experience: transition into the lab, transition into VR, transition through VR, transition out of VR, and transition out of the lab. In the next stage, walk-through of the experience, we led two small groups separately through the existing prototype. Participants were encouraged to "think aloud", while we carefully observed and took notes of their behaviours and responses. After both groups had completed the walk-through, both groups together completed an oral reflection on how aligned the current prototype was with the "perfect" ones they envisioned previously. We prompted them with questions to facilitate discussion. Finally, we helped idea prioritization on the affinity diagram map and created an action plan to move forward with the next prototype iteration.

5.6.3 Results

Here we present the results from the design exercises, which were generated by the participants and then categorized into higher-level categories for each transition type through facilitation by our team.

Into the Lab: tactile stimulus; sensory information. Participants suggested that the initial arrival into the lab should place people at ease and set the tone for the experience as a whole. Most research labs typically are very sparse rooms with LED lighting and neutral colours. This tends to give people the feeling of a sterile medical clinic. Therefore, participants suggested a dark room with dim lights, nature and ambient sounds, and incense to place people at ease.

Into VR: tactile stimulus; calming effect. Participants suggested gradually building on the calming effect by placing small, twinkling lights around the room and having a space welcoming a meditative practice, such as cushions to sit on. Participants also suggested

adding foreshadowing elements like leaves on the ground to foreshadow the virtual forest environment to come, and lights above that act as stars that will also be present in the VE.

Through VR: synced sensory stimuli; controlled sensory stimuli. Although not the focus of our study, participants suggested using synced sensory stimuli while people were in VR, e.g., spraying water when they went into the lake or running a fan when there was wind. Participants also suggested controlling what people could sense while they were in VR by using noise cancelling headphones or ensuring a "cone of silence" surrounded them as to not break presence.

Out of VR: synced virtual and physical senses; story and narrative continuity. Participants found the exit of VR the most intriguing transition because most VR experiences end with simply taking off the headset into an often bright and disorienting reality, and immediately leaving without reflection. To combat disorientation and ease people back into physical reality, participants suggested reciprocating the "Into VR" transition by keeping the VR screen dark, slowly raising the lights, and playing a gentle narration to signal the end of the experience. Participants thought to have story continuity by book-ending the experience with elements present in the VE.

Out of the Lab: nurturing; creature connection. Participants voiced that to best support accommodation of the AWE experience, people would need a positive and supportive environment. Therefore, they suggested someone physically be there to encourage conversation about the thoughts and feelings that arose before, during, and immediately after the AWE experience. Participants also suggested using warm and cuddly props like furniture, beverages, or pets, to support physical comfort that might mentally open a person to a potentially profound experience.

5.6.4 Discussion

Our design elements that we hypothesized would support effective transitions were well aligned with the participants' imagined "perfect" transitions, generated before seeing the prototype. Thus, these design elements show promise in supporting the gradual transition into and out of AWE.

Several creative solutions emerged from the design activities that centered around creating story continuity, syncing virtual and physical sensations, and solidifying the connection to nature. While many of the elements participants listed were already in our design, we implemented those unique elements that were both feasible and within the scope of our project: nature sounds of the forest at night, including wind and crickets; small, yellow tea lights to simulate fireflies; string lights behind black curtains to simulate stars at night, and leave them on for post-VR experience when immersant takes the headset off. Other ideas, such as using a float tank to simulate space and having live animals were not in the scope of the project but are certainly worth exploring.

5.7 Case Study

To explore the potential of set and setting for supporting profound emotional experiences in VR we conducted a case study. We focused specifically on one VR experience designed to support awe. We collected introspective and behavioural data relating to transcendent emotions and presence using validated instruments, as well as semi-structured exit interviews to better understand the experience of each participant. We used two behavioural measures: a self-image drawing (Bai et al., 2017) and pen-drop task (Rosenberg et al., 2013), to study the effects on diminished self-size, prosociality, and creativity–all correlates of self-transcendent emotion of awe. We split participants into two groups, the full transitions experience and the VR-only experience, in order to gain a deeper understanding of how participants experienced the set and setting elements compared to a typical lab environment. We used this case study as an opportunity to further explore creative solutions for set and setting of profound emotional experiences in VR.While primarily interested in understanding participants' experience, we included some quantitative measures to explore potential trends in the data to inform future research with larger samples.

5.7.1 Participants and Methods

We again wanted a purposive sample that was familiar with VR and 3D games in general but, as opposed to the design refinement phase, were naïve to the AWE project. This way we could concentrate on the transitional design elements without having to help with equipment. We recruited 16 participants through social media ads and snowball sampling (ages 22-46 years $M = 30$ years; 4 females).

Participants were assigned to either the full transitions (FT) (N = 8) or the VR-only (VRO) group (N = 8) based on the timeslot they have signed up for. Upon entering the lab, participants signed a consent form and filled out a demographics questionnaire. Next, those in the FT group were lead to the next room, while in the VRO group they were invited to start the VR experience in the same lab space.

After the VR-experience, immersants engaged in reflective journaling and completed a self-drawing sketch (Bai et al., 2017). Next, they filled out two questionnaires and participated in a 5-10 min. long semi-structured interview about their experience from the moment they walking into the lab to the present moment. We video-recorded the interview with an iPhone 6S. At the end of the interview, the researcher "accidently" dropped a stack of pens, while reaching to turn off the recording in accordance to the pen-drop task (Rosenberg et al., 2013). We recorded how quickly and how many pens participants helped the researcher to pick up. At the end, participants were verbally debriefed. The study took under an hour.

Interviews and journal entries were analyzed in NVivo 12. We used thematic analysis (Nowell et al., 2017) with a hybrid approach of both inductive and deductive coding to examine themes within the data. This approach complemented our research questions by

allowing the tenets of our three design pillars to be integral to the process of deductive thematic analysis while allowing for themes to emerge directly from the data using inductive coding. Drawings were analyzed for creative expressiveness based on expert ratings using the consensual assessment technique (CAT), a "gold standard" of creativity assessment with good discriminant validity and inter-rater reliability (Baer and McKool, 2009). Three illustration experts independently rated the drawings in relation to one another for creativity on a scale from 1 (low creativity) to 10 (high creativity). Additionally, we counted the number of squares a drawing of oneself took as a measure of "small-self" (Bai et al., 2017). Both creativity (Chirico and Yaden, 2018) and small-self (Bai et al., 2017) are associated with experiences of awe. Reaction times of pen pick-up were calculated from the recordings and, together with the number of pens picked up, served as a measure of prosociality (Rosenberg et al., 2013) also associated with awe (Stellar et al., 2017).

5.7.2 Results

5.7.2.1 Questionnaires

As the main goal of the quantitative measures was to explore the potential trends in the data to inform future research, we only present descriptive statistics. Future studies are planned with increased participant numbers and statistical power that would allow for inferential statistics comparison. Medians are used because the distribution is skewed. In the Transcendent Emotions Questionnaire, we observe a trend that participants reported feeling more fearful in the VRO group ($Median = 23.0$) compared to the FT ($Med = 2.5$). On the other hand, we see a trend where participants reported feeling more awe, humility, and wonder in the FT (awe $Med = 69.5$; humility $Med = 66.0$; wonder $Med = 68.0$) compared to the VRO group (awe $Med = 50.0$; humility $Med = 42.0$; wonder $Med = 44.0$). Measures of curiosity and physical comfort were virtually the same for both groups. In the IPQ, we found a trend where participants reported higher general presence and involvement in the VRO (presence $Med = 6.0$; involvement $Med = 10.0$) compared to the FT group (presence $Med = 5.0$; involvement $Med = 8.0$). We also found a trend that participants felt higher spatial presence and experienced realism in the FT (spatial $Med = 8.0$; realism $Med = 3.0$) compared to the VRO group (spatial $Med = 7.5$; realism $Med = 0.5$).

5.7.2.2 Behavioural Measures

In the self-image drawing task, the size of the participants' self-image tended to be smaller, indicating smaller perceived ego, in the FT ($Median = 9.5$ squares) compared to the VRO group ($Med = 29.5$ squares). Expert judges rated the FT drawings ($M = 6.83$, $SD = 2.15$) more creative than the VRO group drawings ($M = 4.00$, $SD = 2.20$). In the pen-drop measure, the pickup rate tended to be similar for those in the FT ($Med = 8.5$ pens) and the VRO group ($Med = 8$ pens). Time to pickup the first pen was similar in both groups:

FT (*Med* = 1.5 sec); VRO (*Med* = 1.4 sec). Time to pickup all pens tended to be shorter for the FT (*Med* = 4.2 sec) compared VRO (*Med* = 6.3 sec).

5.7.2.3 Semi-structured Interviews

We explored five major themes in the data relating to our design goals: child-like wonder, perceived agency, transformation, transitions, and multisensory components. We report quotes from participants with (P#), ranging from P11-P26. We add "FT" and "VRO" to the end of P# where participants experienced the full transitions and VR-only, respectfully.

Theme 1: Child-like Wonder

All but one participant in the FT group talked about how they experienced curiosity, exploration, and play. There was a general sense that the physical space felt *"dreamy"*, and feeling like they were on a journey or spiritual quest because there were elements that seemed hallucinogenic with many glowing and seemingly magical artifacts. The whole experience seemed *"like a fairy tale"* (P26FT). Those in the VRO group also mentioned they *"felt like a child"* while walking in the forest in VR, due to the playful-like qualities of the Sprite and the ability to chase it, but not outside of VR. Participants found the elements in the physical environment were intriguing: "*What is this? What is that? How can it affect my experience? I was expecting magic powers from them.*" (P26FT) And when these elements seemed to have their own life, it added depth to the experience, suggesting that there is more to the story:"*when you come out, you get this feeling like something is happening because you're out and then the fire is gone, the talisman is on the thing*" (P12FT)

Theme 2: Perceived Agency

All participants in the FT group talked about their perceived agency both outside and inside the VR experience. They also found the ability to choose a talisman gave them a sense of agency, wondering what might have happened if they had chosen another: "*I think having that piece of choosing the talisman was great for both engaging, feeling like a part of the story or what was happening as well as that little bit of exertion of will and the meaning that I would put into choosing the frog.*" (P15FT) These participants also voiced wanting to explore the VE more, compared to the VRO group. For both groups, there was a strong desire to move more in the underwater and space scenes. Many participants liked having the freedom to move around the forest, but felt some tension after they jumped in the lake because they no longer had that perceived agency. This discrepancy between the initial agency and lack of it in the last phase of the VR experience was even stronger in the FT group, because participants were provided with a lot of agency in pre-VR. However, despite this drastic and salient change in the amount of agency, some participants appreciated it, as that allowed them to find a new way of experiencing VR: "*I'm used to being very active within VR, so having a passive experience was nice. It was a different way of using it than I was used to and felt like an interesting and productive one.*" (P15FT) It was supporting reflection in some participants on how they experience the world, and how slowing down and just taking in the experience can be valuable.

Theme 3: Emotional and Perceptual Shifts

Participants talked about transformations especially relating to emotional and perceptual shifts they experienced. These perceptual shifts could be an indication of the first step towards a self-transcendent experience (Stepanova et al., 2018). Those in the FT group reported shifts in affect, e.g., *"feeling more calm"* [P12FT, 13FT]. Moreover, many felt like the physical environment itself afforded a sort of ritualistic or spiritual journey [P11FT, 15FT, 19FT, 25FT]. There seemed to be a lot of resonances with past peak experiences of hiking and nature that helped with supporting self-transcendent emotions like awe. And, the artifacts outside VR seemed to provide a transformation of state and expectations: "*Well it was an amazing transformation. I thought it was really effective. It was really, I mean, I could imagine being in a space like this* [lab] *and there's clutter. I think that was very effective, just to bring in another state.*" (P25FT) Equally in both groups, many people had perspective changes related to the overview effect of seeing the Earth from space in VR:"*I've seen Google Earth and stuff but in VR I haven't seen Earth before. So, it's really nice. It made me... gave me perspective*" (P22VRO). Participants admired the vastness of our planet, which is the trigger of a self-transcendent emotion of awe (Chirico and Yaden, 2018; Keltner and Haidt, 2003): "*It was pretty neat when you went by the Earth there. I realized that, when you see the little dots at night, there's a lot of people!*" (P16VRO).

Theme 4: Transitions

Openness and Readiness to the experience: Participants in the FT group reflected on how the pre-VR space helped them "*change the mindset between your usual day-to-day and getting more into the experience*" (P12FT), made them "*more open to the world that is being created*" (P15FT) and assisted with "*having that suspension of disbelief that you need to enjoy a VR experience*" (P19FT). Even before entering the experience space, "*having the lamp as a starting place for coming in helped set the stage*" (P15FT). Participants speculated the physical space shaped their overall experience: "*Lighting, different kinds of contextual environmental sound, the little bit of projection... The whole experience would have been completely different and I think way less interesting if it wasn't for that container*" (P25FT). Conversely, participants in VRO group were thinking less of the effect of the physical space on the experience and had very short recollections of the experience in that part: "*I don't know, just waiting for the experience*" (P23VRO).

Continuity: Some of the participants appreciated how there was connection between different parts of the experience throughout from the entrance to exit: "*I really appreciated it being a kind of beginning to end kind of experience rather than something that's just putting a headset on and taking it off kind of thing*" (P19FT). The connection of elements of physical environment and objects in the VE created the sense of experience completeness: "*there was a big resonance for me between having the torch and having the lamp, and then having the guided light that takes your through it*" (P15FT). Different components that were

appearing throughout "*helped to provide more mental hooks for the experience to hang onto, so that was neat*" (P15FT).

Accommodation: The post-VR phase in FT group provided space for participants to reflect and accommodate their experience. One participant reflected on exiting VR: *"A lot of VR experiences you go do, you get shoved out the door as soon as you take the headset off. So, it's nice where there's somewhere where you can either reflect on your own thoughts ... Just kind of compounds the immersion you just felt"*(P19FT).

Theme 5: Multisensory Components

It is not surprising to find many accounts of sensations in the FT group, given that we designed the full transitions environment in relation to the main five human senses. Participants noticed these elements and found them pleasant: forest floor, hot chocolate, s'more, morning light, fire, darkness, lamp, night sounds of crickets, tent lighting, stool, camping chair, and projection day/night forest. However, some participants found the camping chair seemed too small for them making them feel not welcomed and the costumes felt too hot after being in VR. Those in the VRO group found the lab space unremarkable for the most part. They focused solely on the VR experience itself, primarily on visuals and in a few cases the audio. The most discussed item in terms of its sensory dimensions was the cup of hot chocolate: the temperature was creating an inviting environment: *"it really made that warm sensation, you felt welcome"*(P12FT), that was enhanced by the olfactory dimension: *"sofa is cozy and chocolate smells good"*(P26FT), as well as the taste: *"having the hot chocolate and that physical warm, tactile as well, experience as part of it was good, was nice, it made me, as I was getting ready to come back to the front area, decided to go back and have a last sip of that to close off that sensory piece of the experience as well"*(P15FT). Interestingly, the warm temperature of hot chocolate in combination with the rest of the environment by contrast was giving a perception of the physical space being colder: *"it's more about the night and it's chilly and fresh air and you want to get something hot"*(P11FT).

The sounds both in virtual and physical environments were often discussed, and were usually making participants feel soothed or relaxed. Sounds in the physical space were making that experience more immersive: *"I really liked coming back to the sound of the space. And somewhat in a sense of re-emerging out of the virtual world into the real one"*(P25FT). The lighting of the room was also contributing to the experience: *"the lighting effect, like the scene inside the teepee right before you take off the headset in the daylight, the light effects were really nice on the bedding, so that was cool"* (P19FT).

5.8 Discussion

We described our design process that explored the design elements most important for promoting profound emotional experiences. In the case study, we found that our intended design pillars were mostly well supported but there is still much work to be done with the virtual experience itself. The qualitative descriptions of user experiences can be useful

to designers in themselves. Here we discuss common user experience themes that might be helpful for designers to consider for supporting profound emotional experiences in VR. Because we only explore one case study, we cannot provide any concrete generalizable design guidelines at this time. Our work will potentially contribute to a more robust set of design guidelines in the future.

5.8.1 Considerations for Supporting Profound VR Experiences

Guided by our design process and existing literature on gradual transitions, we identified and prioritized five themes that were important for supporting profound emotional experiences in this case study. Based on these themes, we found that gradually transitioning participants into and out of the VR experience might help support profound emotional experiences. In our design, the pillars of childhood wonder and perceived agency were better supported than self-transcendence. This highlights that complex and understudied constructs such as STEs are lacking sufficiently explored guidelines for how to design for them. However, here we discuss three user experience themes relating to set and setting that can be further explored to support emotionally profound experiences in VR.

1. Foreshadow in-game experience: Results from the theme "child-like wonder" suggest using fantastical or ambiguous stimuli can help get immersants excited and in the right headspace for the in-VR experience. The themes "transitions: continuity" and "multisensory components" suggest a blending together and more seamless transition from real to virtual world may help increase presence in VR, and thus a more effective VR experience aimed to support a profound emotional experience. The multisensory aspects also seemed to contribute to a suspension of disbelief. Those in the FT group felt the experience would be completely different within a lab setting. In fact, the VRO participants reported it felt like a researcher was conducting an experiment rather than a guide facilitating an experience. These results are in keeping with sensory adaptation as an important component of transitioning out of VR (Knibbe et al., 2018).

The pre-VR space sets the expectations for VR, and as such, all of its components need to adhere to the principle of continuity. This applies not only to the specific objects and the setting, but also to the 'rules' of the world, such as how much agency the immersant gets over their choices.

2. Establish agency and control: Results from the theme "perceived agency" point toward gradually giving the immersant more control as a way to ease them into the experience and movement interactions. Small ceremonies, such as choosing a talisman and throwing it in the fire, may help shift the immersant's mindset to "openness and readiness to the experience". Based on the interview responses from participants, the set and setting of the full transitions experience both prepared them for the virtual experience and gave a reflective space to accommodate that experience. The ritualistic use of putting on costumes, selecting a talisman, and enjoying a hot beverage all set the tone and mood for having a

spiritual-like journey or quest in the experience. These results are in keeping with prior literature on the use of ritual for providing profound and subtle experience (Kitson et al., 2018b; Leary et al., 1971).

Always get consent and provide a way for the immersant to stop the experience at any time without repercussions; knowing how to disengage with VR can ease anxiety of the immersant. Similarly, any use of "multisensory components" should be secure and possible interactions easily known to the immersant so that they can be discovered without hesitation. Self-transcendence, as well as other profound positive emotions, is a very personal and intimate experience that requires trust between immersant and designer to allow participant to open up to the experience.

3. Make and experience art: Results from the theme "child-like wonder" suggest that designers provide engaging and striking stimuli, such as visuals, audio, or other "multisensory components". One way to also help support "perceived agency" is by giving the immersant freedom to create and express themselves, which could be through manipulating the environment by various sensors or personalizing part of the experience. The use of "multisensory components" provides the opportunity to have the immersant interact with the experience, ultimately investing the immersant in the experience and more likely to have a self-transcendent experience. This relates to the art perception principle of *Beholder's share* introduced by Ernst Gombrich (Gombrich, 1961). He describes how art experience emerges in the interaction between the art piece and the interpretation of the observer. The design or art needs to leave space for the participant's imagination to fill in the gaps, if there is no mystery or ambiguity left, there is no room for the observer to engage and contribute. Letting participants be intrigued by the elements of the environment and make their own interpretation will allow them to actively co-create the experience. Our results are in keeping with prior research that shows physical interfaces and a narrative help transition people into VR and keep them immersed in the experience (Mine, 2003; Pausch et al., 1996).

Overall, our user study points to the value of *set and setting* and perceived agency both inside and outside the VR experience. It also suggests that our intended goal of supporting profound emotional experiences in VR needs more exploration; although it does appear we are heading in a positive direction. The quantitative measures point toward the set and setting better supporting transcendent emotions, presence, pro-sociality, and creativity motivating new research questions about its' effects. Our results support prior research that advocates for using gradual transitions for VR (Jung et al., 2018; Knibbe et al., 2018; Men et al., 2017; Smolentsev et al., 2017; Sproll et al., 2013; Steinicke et al., 2009, 2010), and build on existing frameworks for supporting STEs with positive technology (Botella et al., 2017; Chirico et al., 2016; Gaggioli et al., 2016, 2017; Kitson et al., 2018a; Riva et al., 2016; Yaden et al., 2018).

5.8.2 Limitations, Generalizability, and Future Directions

We identified several design elements that were important for supporting profound experiences in an immersive location-based space. These were, however, only examined in one specific instance and we must be cautious in generalizing to other projects. There may be other design solutions we have not identified, and there are certainly more ways to create ceremony and gradual transitions into and out of VR. What we can say, based on prior literature, is that VR experiences aiming to support awe can benefit from a "set and setting" (Quesnel et al., 2018; Stepanova et al., 2019a,b). Additionally, our results are supported by years of industry using exhibits around a digital experience to enhance the emotional quality. For example, Disney uses haunted houses to prime fear in people in line (Mine, 2003; Mine et al., 2012). Set and setting has already proved to be important in the emotional outcome of psychedelic trips (Carhart-Harris et al., 2018; Leary et al., 1971), another kind of non-ordinary reality, and it seems like this too is the case with VR.

The question now is what are the minimal conditions of set and setting to support a profound emotional experience in VR? And, how do our results generalize to different VEs with different target profound emotions? We have explored the potential, and now we can hone in on these specific research questions. A mixed methods approach in the next studies will provide greater validity and confirmation of the impact of set and setting for profound emotional experiences in VR. In the future, we hope to provide a robust set of design guidelines.

5.9 Conclusion

We contribute a case study and discuss common themes for creatively exploring and developing experiences around both entering and exiting VR with ceremony and gradual transitions. (1) We conceptualize the design by creating design pillars, and then ideate design elements that support those pillars. We use physical prototyping and storyboarding to rapidly prototype our designs. (2) We refined our design to generate the ideal product and then honed in on those important design elements afterward. (3) Case study is a flexible way to check our design assumptions and iterate on our project.

This process allowed us to successfully explore and prototype in this design space.Our results suggest set and setting are important in supporting profound emotional experiences in VR. User experience themes included using elements to foreshadow the in-game experience, establishing agency and control, and making and experiencing art. We encourage the design community to further explore the role of these themes and set and setting design in supporting different VR experience for profound emotions. Collectively developing design guidelines in this emerging space of profound VR experiences would allow us to make these experiences more accessible, ultimately improving human condition and well-being.

5.10 Author Contributions

AK and BR conceived the main idea of the article. AK, ES, IA, and NW conceived and developed the technical setup. AK, ES, IA, and NW collected all data. AK and ES carried out qualitative data analysis. AK wrote the first draft of the manuscript, while ES, IA, NW and BR contributed to the final writing of the manuscript by giving suggestions regarding the issues related to the rhetoric and to the literature. BR supervised the entire work. All authors contributed to the manuscript, read, and approved the final version.

5.11 Acknowledgments

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5.12 Afterword

In reflecting about this thesis as a whole, I realized that we did not acknowledge where some of the design elements in this experience came from. This study was inspired by creating ceremony, which is strongly tied to culture. It is important to be mindful of borrowing from different cultures in a way that is creatively open and culturally sensitive. How might we design mindset and setting without misappropriating? One way is to reflect about each choice and research where that ceremonial practice or object came from. We might ask, is it necessary to tie this design element to a specific culture? For example, in this paper we chose to use masks depicting animals. Masks have been used in many different cultures and, thus, have different meanings and significance. It is important to recognize that and be sensitive to the potential impact in using certain kinds of masks may have on different cultures. Another way to address misappropriation is to have creative collaborations with ceremonial practitioners. A co-design approach would go beyond cultural advising and can help ensure we are engaging with ceremonial practices in a respectful and responsible manner.

Chapter 6

Lucid Loop: A Virtual Deep Learning Biofeedback System for Lucid Dreaming Practice

This chapter has been published in the ACM Digital Library (2019).
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6.1 Abstract

Lucid dreaming, knowing one is dreaming while dreaming, is an important tool for exploring consciousness and bringing awareness to different aspects of life. We present a proof-of-concept system called *Lucid Loop*: a virtual reality experience where one can practice lucid awareness via biofeedback. Visuals are creatively generated before your eyes using a deep learning Artificial Intelligence algorithm to emulate the unstable and ambiguous nature of dreams. The virtual environment becomes more lucid or "clear" when the participant's physiological signals, including brain waves, respiration, and heart rate, indicate focused attention. *Lucid Loop* enables the virtual embodied experience of practicing lucid dreaming where written descriptions fail. It offers a valuable and novel technique for simulating lucid dreaming without having to be asleep. Future developments will validate the system and evaluate its ability to improve lucidity within the system by detecting and adapting to a participants awareness.

6.2 Introduction

Lucid dreaming is being aware one is dreaming while in a dream, allowing the dreamer to take control and do anything they want (LaBerge, 1990). Lucid dreaming can be the ultimate entertainment, but is also a space to solve problems, be creative, rehearse situa-

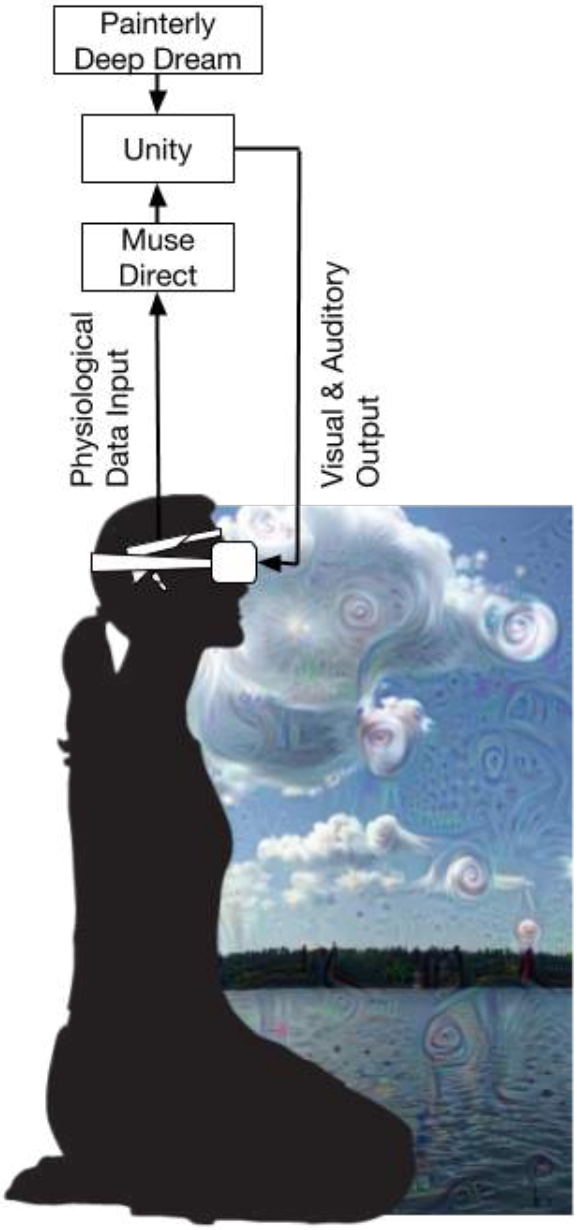

Figure 6.1: Lucid Loop system schematic. Painterly and *Deep Dream* creatively generate visuals to emulate dreams. The virtual environment becomes more lucid or "clear" when the participant's physiological signals indicate increased awareness.

Band	Range	State
Gamma γ	30-50Hz	hyperactive
Beta β	13-30Hz	alertness
Alpha α	8-13Hz	relaxation
Theta θ	4-8Hz	meditative
Delta δ	0.5-4Hz	deep sleep

Table 6.1: EEG Frequency Band Interpretation

tions, and work through psychological issues (Schädlich and Erlacher, 2012; Stumbrys et al., 2014). Yet, learning to lucid dream takes time and practice, and not everyone is convinced by, nor successful with, traditional training methods that primarily use written and audio dream guides. *Lucid Loop* is a virtual reality (VR) experience that uses biofeedback from brain waves, heart rate, and respiration to help participants practice lucid dreaming awareness. Participants will receive artful visual feedback based on Deep Convolutional Neural Networks (DCNNs) in a VR head mounted display (HMD).

To the best of the authors' knowledge, this is the first VR experience that uses biofeedback to generate artistic representations of lucid dreaming practices. The main scientific contribution is twofold: improving our understanding of lucid dreaming awareness and creating a design of a new tool for simulating lucid dreaming without having to be asleep. We are developing this tool, which we will test and iteratively refine through both quantitative and qualitative measures. The goal is to have the VR experience directly respond to participants' physiological states of awareness that closely map to states of lucid dreaming awareness in order to gain its many benefits.

6.3 Related Work

6.3.1 Deep Convolutional Neural Networks and Art

DCNNs are mainly used to classify images, objects, and faces (Krizhevsky et al., 2012), and their analysis requires innovative visualization methods. Google Researchers developed a novel visualization method called *Deep Dream*, whose goal is "to check what [the] network learned during training; [provide] a new way to remix visual concepts or perhaps even shed a little light on the roots of the creative process in general" (Mordvintsev et al., 2015).

This *Deep Dream* style essentially fuses the content from one image and the style from another into one novel image, resulting in an image with a dream-like quality (Figure 6.1). Researchers/Artists have begun to take advantage of this artistic quality to express visual creativity (DiPaola and McCaig, 2016; McCaig et al., 2016).

6.3.2 Virtual Reality and Biofeedback for Awareness

In the context of lucid dreaming, awareness is defined here as the explicit recognition of one's current experience. The goal of lucid dreaming and similar practices, such as meditation and yoga, is increasing awareness. In doing so, we can understand ourselves and the world around us on a deeper level (Holecek, 2016). Thus, the practice of lucid dreaming itself is beneficial because it provides us an opportunity to question reality and become more aware of our surroundings and internal physiological state.

One way to practice awareness of our physiological states is through biofeedback, a training technique to help people learn how to change their physiological response patterns to improve their mental and emotional state (Gaggioli et al., 2017). Neurofeedback is a specific type of biofeedback where participants respond to a display of their own brainwaves; specific bands of brainwaves have been correlated with different physiological states (see Table 7.1). To enhance the experiential qualities of biofeedback, several researchers have added VR—for a review see Kitson et al. (2018a). For example, *PsychicVR* maps concentration to levitation and increased virtual fire to promote mindfulness (Amores et al., 2016). *Pulse Breath Water* is a VR experience with affect estimation in sound to promote relaxation, calm, engagement, and breath awareness (Prpa et al., 2017). We use biofeedback and VR for the same reasons previous researchers have, with the addition that other methods of learning lucid dreaming awareness can be inaccessible and challenging, e.g., written guides, or more expensive and carry higher risks, e.g., transcranial alternating current stimulation (Voss et al., 2014).

6.3.3 Technology Mediated Experiences of Altered States

Altered states of consciousness can provide people with powerful and sometimes life-altering experiences. Technology can support these experiences in a more accessible way than others, such as psychedelics and religious ceremonies. Moreover, technologies like VR can amplify immersion and realism beyond other media, thus enhancing the experience and potential positive outcomes. Yet, many technologically mediated experiences of altered states, especially lucid dreaming, lack empirical studies to back their claims. *SoundSelf* (Arnott, 2017) and *V.DREAM* (Alin, 2018) are VR experiences that use psychedelic-inspired lights and sounds to try to induce trance-like states. *Somnai* is a guided lucid dreaming-inspired mixed reality experience with intricate multisensory stimuli (Entertainment, 2018).

There exist a few research-based designs. One such experience is *Hallucination Machine*, which uses DCNNs and panoramic videos of natural scenes, viewed immersively through an HMD. *Hallucination Machine* was shown to phenomenologically induce an experience similar to psychedelics, although the temporal distortion commonly associated with altered states was not evoked (Suzuki et al., 2017). However, this system only allows passive viewing from one perspective and does not enable interactivity that would help participants

reach this altered state naturally. Interactivity is important here since lucid dreaming requires the dreamer to actively move from non-lucid awareness to lucid, whereas psychedelics automatically provides hallucinations without active participation.

6.4 Lucid Loop

Our aim is to simulate the visual and auditory aspects of lucid dreaming using *Deep Dream* to produce an embodied experience where participants may practice lucid dreaming awareness via biofeedback and VR. Visuals and sounds will become clearer, or more lucid, as participants' increase their awareness, similar to actual lucid dreaming (Gackenbach and LaBerge, 2012).

In *Lucid Loop*, the participant wears a *Muse 2* EEG that also detects heart rate and respiration, and an HMD, e.g., Oculus Quest, while experiencing a short, looping virtual experience generated by the *Deep Dream* algorithm (see Figure 6.1). 3D spatialized audio will be presented through headphones to give the listener the impression of a realistic sound source within a 3D environment. *Muse 2* detects participant's brainwaves that are correlated with certain states (Table 7.1). In *Lucid Loop*, participants are given positive visual and auditory feedback about their awareness when their physiology changes similarly to what is observed for lucid dreaming. That is, visuals and sound increase in clarity when EEG β and γ band powers increase, α and θ band powers decrease, and heart and respiration rate increase; vice-versa when visuals and sounds decrease. Lucid dreaming studies show elevated levels of autonomic nervous system activity occurs 30sec before the onset of a lucid dream, as evidenced through respiration rate, heart rate, and skin potential (LaBerge et al., 1986). EEG studies show increased β band power over parietal regions and γ in frontal regions during lucid compared to baseline REM sleep (Holzinger et al., 2006; Voss et al., 2009).

We chose to use artistic representations of data as opposed to graphical or more simplistic representations for two main reasons: one because understanding raw data for the average person is not intuitive; two because we wanted the experience itself to be intrinsically rewarding even if one is unsuccessful in trying to change their physiological state.

6.4.1 VR Visual Design

We use an HMD with six degrees-of-freedom head-tracking to enhance the immersive experiential qualities of lucid dreaming and allow the participant to look around naturally. *Hallucination Machine* used 360 panoramic video with *Deep Dream*, which can give a more realistic simulation (Suzuki et al., 2017); however, we chose a computer graphics approach to allow real-time modification of any element, providing more flexibility for future iterations and control over experimental variables. *Lucid Loop* will be created in Unity, with visuals modified using *Deep Dream* and Painterly—a non-photorealistic rendering system that uses

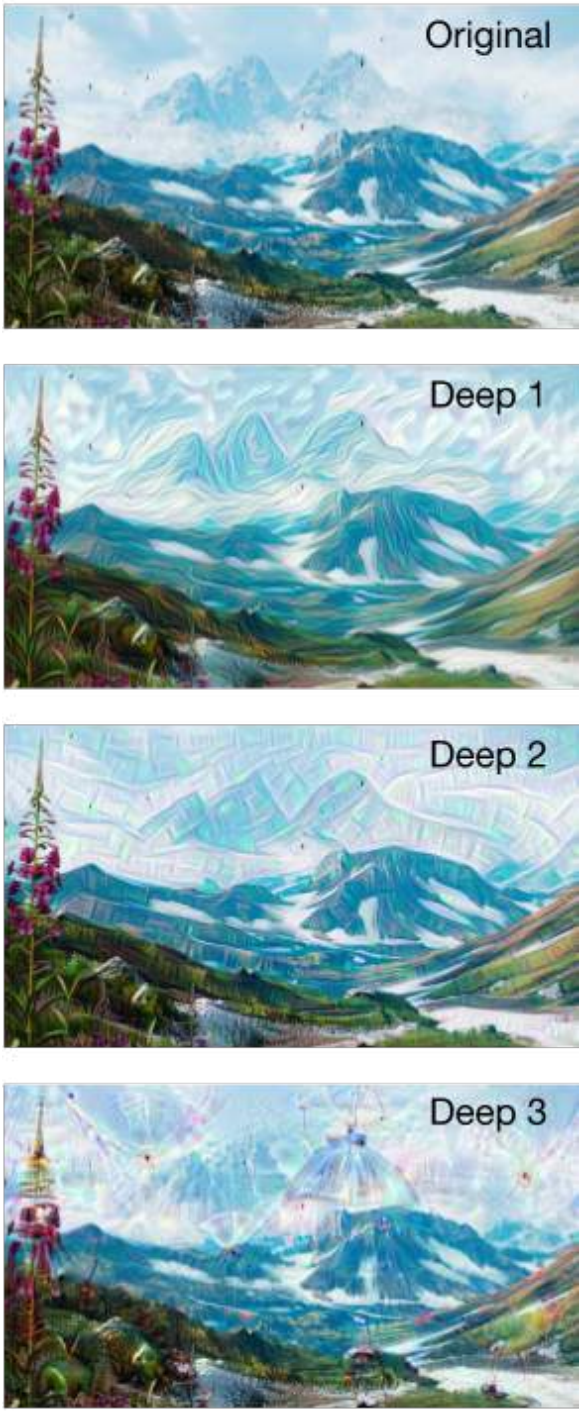

Figure 6.2: Unity scene (Asset Store: *Alpine Environment*) with *Deep Dream* (deepdream-generator.com) that makes different outputs depending on layer depth, from low (top) to high (bottom)

algorithmic, particle system and noise modules to generate artistic colour palettes, stroking and styles (DiPaola, 2007). In *Lucid Loop*, we aim for a visual effect similar to lucid dreaming awareness, where bizarreness is needed for the dawning of dreaming awareness, but once achieved, the lucid dream scene is relatively realistic (Gackenbach and LaBerge, 2012). We are inspired by research on the phenomenology of lucid dreaming for introspection and VR (Kitson et al., 2018b), which suggests the use of nature, abstraction, clarity, curiosity, and perceived autonomy for VR design. However, research on the phenomenological differences between lucid and nonlucid dreams show mixed results (Gackenbach and LaBerge, 2012). We plan to test these lucid dreaming components in future phenomenological experiments.

Lucid Loop will be an open, nature scene with other interactive elements that provoke curiosity. DCNN imagery will provide a level of abstraction needed for a dream-like effect, e.g., Figure 6.2. The image layers themselves will range from very abstract to completely clear, mimicking levels of clarity in lucid dreaming. We do not input physiological signals directly into the DCNN yet since we first aim for high quality, artistic content that changes in real-time, and current technology does not yet allow for this. Future iterations will have physiological signals generate deep dream content in real-time.

6.4.2 Biofeedback Mapping

The participant experiences real-time biofeedback in the form of creative visuals and audio that are mapped to data from *Muse 2*, a wearable headband comprised of five frontal EEG electrodes including one baseline; one photoplethysmogram (PPG); one gyroscope; one accelerometer. Heart rate is calculated from PPG, and respiration from a combination of PPG and gyroscope. Brain waves (uV) are read from EEG electrodes, where a Fast Fourier Transformation then computes the power spectral density of each frequency on each channel. We take the log of the sum of the power spectral density of EEG data over a frequency range (i.e., γ, β, α, θ, and δ) to calculate the absolute power bands. The mean γ, β and θ power levels of all EEG electrodes are then normalized to a score between 0 and 1. The score is 0 if <= 20th percentile of the distribution of band powers and 1 if >= 80th percentile. The higher the score, the greater the change in band power. Thus, if a participant increases their γ, β and θ scores, this indicates that lucidity is also increased and the image and audio will become clearer. Likewise, when γ, β and θ scores decrease, then lucidity decreases and the image and audio will become more abstract. Increased heart rate and respiration will also contribute to a clearer or more lucid image, but to a lesser extent since these physiological responses are innervated by both sympathetic and parasympathetic nervous systems so the meaning of their responses is less evident.

6.5 Research Design and Implementation

This research will be conducted in two phases: validating the system components; conducting more extensive testing and an evaluation of the system's ability to increase lucid dreaming awareness.

6.5.1 Phase 1: Test and Validate Components

First, we will measure physiological signals from brain waves, heart rate, and respiration to validate participants' experience of lucid awareness. We will collect data from participants wearing *Muse 2* with a VR HMD over top. We will measure a baseline EEG reading using the Klimesch Technique, where we measure each band during two minutes of eyes open and one minute of eyes closed (Shiffrin and Schneider, 1977). This provides a measure of individual frequency for each band. We will collect and record data with Muse Direct, a visualization and recording tool for *Muse 2*.

6.5.2 Phase 2: Evaluation of System

We will use a mixed methods approach by triangulating data to evaluate *Lucid Loop*. Physiologically, we will measure outputs from brain waves, heart rate, and respiration. We will look at self-reported responses from both validated questionnaires and semi-structured interviews based on cued-recall debrief—a method that allows the participant to fully experience the system without disruption and avoids memory bias by showing the participant a first-person perspective recording of their experience (Omodei and McLennan, 1994).

6.6 Conclusions and Implications

We propose a novel VR deep learning biofeedback system for lucid dreaming awareness. Components of *Lucid Loop* have already been developed, but the combination of them is what makes this system unique. Moreover, an embodied experience of practicing lucid dreaming awareness without having to actually be asleep is also new. *Lucid Loop* has the potential to provide a powerful new tool to complement the increased interest of research into lucid dreaming and its practices, whose benefits contribute to well-being. *Lucid Loop* uses direct feedback to playfully support awareness of one's state, ultimately helping to self-regulate one's state and enable more frequent or sustained lucid dreams.

6.7 Acknowledgements

We gratefully acknowledge funding from the Social Sciences and Humanities Research Council of Canada. We thank all the collaborators on this project including Reese Muntean, Andy Bacon, Patrick Pennefather, and Sheinagh Anderson.

6.8 Author Contributions

AK, SD and BR conceived the main idea of the article. AK and SD developed the artistic aesthetics with consultation from Reese Muntean. SD developed the DCNN output of the visuals and AK developed the technical components with the help of Andy Bacon. Patrick Pennefather and Sheinagh Anderson composed the audio. AK wrote the first draft of the manuscript, while SD and BR supervised the entire work. All authors contributed to the manuscript, read, and approved the final version.

Chapter 7

An Exploratory Study on an Immersive Environment and Neurofeedback System with Modified Deep Dream 360 Video to Support Lucid Dreaming Practices

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7.1 Abstract

Lucid dreaming is the awareness of being in a dream, and with that comes the potential for dream control and living out your fantasies. Besides being fun, there is potential for healing, growth, and well-being. We explore the potential for Lucid Loop—a neurofeedback-based immersive environment that utilizes 360 video and audio in a head-mounted display (HMD) device for lucid dream training. A qualitative study with lucid dreamers (N=9) who tried Lucid Loop helped us derive several design considerations: dreaming experience allusions, reality checks, focus points, people in the scene, gamma as focused attention feedback, and HMD immersive environments. Our results show the similarities between lucid dreaming and Lucid Loop, indicating immersive environments' usefulness for training lucid dreaming because of its capacity for emotionality and fluidity between self and environment. Participants experienced a tension between simply noticing and wanting to control how their brain waves influenced the environment through neurofeedback.

Figure 7.1: A person wears an Oculus Quest VR HMD and Muse 2 EEG Headband to experience and influence a lucid dreaming inspired 360 video.

7.2 Introduction

Lucid dreaming, knowing one is dreaming while dreaming, can be the ultimate entertainment, but it is also a space to solve problems, be creative, rehearse situations, work through psychological issues, and have spiritual experiences (LaBerge and Rheingold, 1990; Schädlich and Erlacher, 2012; Stumbrys et al., 2014). Lucid dreaming is correlated with other positive benefits including increased positive mood after waking (Stocks et al., 2020), and higher life satisfaction and self-esteem (Konkoly and Burke, 2019). With all of these potential benefits, people could make use of this phenomenon. Lucid dreaming is typically learned by rehearsing dreams and visualizing becoming lucid, and this technique —called Mnemonic Induction of Lucid Dreams or MILD —has been shown to be an effective strategy for increasing lucid dreaming frequency (LaBerge, 1988; Levitan and LaBerge, 1994). With the MILD technique, one concentrates on the intention to remember to recognize one is dreaming. This prospective memory technique can be done by repeating a short mantra like "next time I'm dreaming, I'll remember I'm dreaming", and imagining oneself becoming lucid in a dream. There are many proposed strategies to help induce lucid dreams, including wake-back-to-bed (WBTB) where one wakes up after some sleep and returns to bed; wake-initiation of lucid dreams (WILD) where one keeps their consciousness while falling asleep and go straight into a dream; and visual induction of lucid dreams (VILD) where, by repetitive visualization, one incubates a dream in which one does a reality check. However, a systematic review found none of these strategies had high reliability; although, of the methods that showed the most promise, MILD was one of the most promising (Stumbrys et al., 2012). Three independent studies that used MILD techniques for lucid dreaming induction found 40% of participants had verified lucid dreams through eye tracking measures and 47.5% subjectively reported a lucid dream (Appel et al., 2020; Erlacher and Stumbrys, 2020; Stumbrys and Erlacher,

2014). Another study with 420 participants found a positive correlation between increased MILD techniques (combined with WBTB method and VILD) and increased lucidity (Aspy et al., 2017). Together, these studies demonstrate the efficacy of practicing MILD techniques for increasing the potential for lucid dreaming.

Another way to increase the likelihood of having a lucid dream is by having competent focused awareness (attention) skills, such as seen in experienced meditators (Stumbrys and Erlacher, 2017; Stumbrys et al., 2015; Wallace and Hodel, 2012). It is still unclear if mindfulness based stress reduction training can increase lucid dreaming frequency (Baird et al., 2019b). However, these same authors suggest the focused awareness component of mindfulness meditation might still be helpful in increasing lucid dreaming frequency. They suggest more research is needed comparing different meditation interventions, such as focused attention and open monitoring. Stocks et al. (2020) have suggested meditation practices could prime positive lucid dream experiences, but more research is needed to determine exactly what meditation practices prime lucid dreams and for how long do people need to practice meditation to see any effect on lucid dreaming.

One tool that may help to learn focused awareness is neurofeedback, a coaching and training technique that helps people learn how to change their neurological patterns in order to improve their mental and emotional state (Gaggioli et al., 2017). Some studies suggest neurofeedback is an effective tool to learn to improve focused awareness in children (Antle et al., 2018; Hillard et al., 2013; Huang et al., 2014), as well as older (65+ years) and younger (early 20s) adults (Wang and Hsieh, 2013). A review on neurofeedback for improving attention suggests current neurofeedback technologies hold promise to provide effective rehabilitation strategies for individuals with impairments of attention, such as ADHD (Jiang et al., 2017). That said, more research is needed to establish a stronger relationship between neurofeedback and focused attention, especially for non-clinical adult populations. One study employed neurofeedback attention training for lucid dreaming using alpha brain waves, and found it did not increase lucid dream frequency (Ogilvie et al., 1982). This is perhaps because more current research shows that beta and gamma, and not alpha, activity is associated with lucid dreaming (Holzinger et al., 2006; Mota-Rolim et al., 2008; Voss et al., 2009) and focused awareness (Lutz et al., 2004; Travis and Shear, 2010). More recent studies have shown promising results using neruofeedback with sleep and dream staging (Haar Horowitz et al., 2018; Semertzidis et al., 2019). What if training focused attention with neurofeedback, namely neurofeedback with gamma brain waves, is effective for training lucid dreaming? We wanted to explore this possibility in this paper.

Another consideration for learning mnemonic induction skills for lucid dreaming is through immersive environments, such as virtual reality (VR) and 360 videos. Lucid dreaming and immersive environments have several parallels. First, in both cases, the self is immersed in a world that appears real yet at the same time is aware the world is a simulation. Second, both have emotional and epistemic affordances (Gaggioli, 2016). The emotional af-

fordances are perceptual cues that are aimed to elicit a deep emotional involvement, i.e., by inducing exceptional appraisals of admiration, wonder, elevation, and awe. The epistemic affordances are cognitive cues that are meant to provide a person with the opportunity to integrate or build new knowledge structures. These are, in essence, structured narratives conceived to trigger reflection and transformative insights. Gaggioli (2016) has identified these two types of experiential affordances that can be integrated into a simulated experience. These same affordances can be applied to dreaming (Metzinger, 2013; Scarpelli et al., 2019). Third, one can experience impossible or improbable situations either through dream content or computer generated simulations. As pointed out in Carr et al. (2020), the mechanisms behind the illusory perception of VR echo that of dream generation; making VR an apt technology for facilitating both dream research and experience. Specifically, Gonzalez-Franco and Lanier (2017) have proposed a model of the cognitive and perceptual mechanisms of simulation generation (VR) that mirror dream generation accounts: bottom-up multisensory processing; top-down prediction manipulations; and sensorimotor self-awareness frameworks. Other research has likewise pointed towards VR's potential ability to help people rehearse and visualize becoming lucid through a virtual experience based on lucid dreaming phenomenology (Kitson et al., 2018b; Schädlich and Erlacher, 2012; Stumbrys et al., 2014). Therefore, immersive environments, compared to other forms of feedback, seem to be the most suitable because of its parallels to dreaming and unique capabilities to integrate multisensory experiences. In this paper, we provide more clarity on the extent to which immersive environments and lucid dreaming are alike and dissimilar. We also explore whether immersive environments could be an effective tool for supporting lucid dreaming practices.

In the combination of neurofeedback and immersive environments, research is still in its infancy. A scoping review paper (Kitson et al., 2018a) shows only a handful of studies use neurofeedback and immersive environments to support mindfulness (i.e., PsychicVR, Virtual Sophrologist, Sensorium, RelaWorld, and Mind Pool). Like Baird et al. (2019b), these studies also looked at mindfulness generally and did not differentiate between open monitoring and focused attention. Still, sensory stimulation technologies such as VR and brain-computer interfaces (BCI) show great promise for furthering our understanding of dreams and how we can better support the experience of them (Carr et al., 2020). Sensory stimulation technologies are devices that evoke physiological responses for sensory modalities such as haptics, vision, olfaction, and audition. In this study, we explore if neurofeedback of gamma brain waves (attention) enhances the MILD lucid dreaming technique, and whether this effect is enhanced when the feedback is in the form of an immersive (audio-visual) environment. We posit that the strong similarities between lucid dreaming and immersive experiences could make the latter a reliable method for lucid dreaming training.

The primary objective of this work is to explore whether using neurofeedback and immersive environments could support lucid dreaming practice through increased focused

awareness (attention) and mnemonic induction skills. While we ultimately strive for a system that trains these techniques effectively and helps people have more lucid dreams, the focus of this paper is not to definitely show the system's effectiveness but rather explore first steps toward that goal. In this paper, we describe the design of Lucid Loop (Figure 7.1), one of the first immersive environment and neurofeedback systems that aim to support lucid dreaming practice through artistic visual and auditory feedback. We also present a study of Lucid Loop where we ask the following research questions:

1. In what ways are lucid dreaming and immersive environments, specifically Lucid Loop, alike and dissimilar? How might this impact the design of an immersive experience that supports lucid dreaming practice?

2. Can we design a neurofeedback and immersive environment to support lucid dreaming practice through practicing focused attention and mnemonic induction skills? If so, what design features support this experience?

We report on the results and analysis of the data collected, compare and contrast lucid dreaming with immersive environments as a way to better understand the parallels and potential for using immersive environments to both enhance and study lucid dreaming practices, and offer design considerations for immersive systems intended for lucid dreaming practice.

7.3 Related Work

We consider our research situated at the intersection of four domains: lucid dreaming, focused attention, neurofeedback, and immersive environments. The connection between all of the different domains is not very well understood and research is just starting to develop. Here we offer the current state of research across these four domains as they relate specifically to our research questions.

7.3.1 Neurofeedback Systems

Most of the technological systems that use neurofeedback are EEG-based. MindFull uses EEG neurofeedback on the focused attention facet of mindfulness. When the user is focused, they see feedback on a tablet. Results show children were able to calm and focus their attention (Antle et al., 2018). MeditAid is another system that uses EEG neurofeedback, this time mapping alpha brain waves (input) with binaural beats (output). Results show the system supported self-regulation of attention compared to monaural beats and no feedback. Their findings suggest that aural feedback can add to distraction, as people strongly prefer quietness during meditation; haptic feedback might better support bodily awareness (Sas and Chopra, 2015). AttentivU is an EEG neurofeedback system integrated into wearable

glasses to detect attentiveness and nudge the user with audio and haptic feedback (Kosmyna et al., 2019). A study with 48 adults showed AttentivU was able to redirect attention of participants back to the task at hand and improved their performance on a comprehension task compared to random and no feedback (Kosmyna et al., 2019). Salehzadeh Niksirat et al. (2017) offer a theory-grounded **Attention-Regulation Framework for Neurofeedback** that was validated through two experimental studies comparing their app *Pause* with an existing app *Headspace*. Their framework includes design suggestions when considering neurofeedback for attention regulation. First, relation response requires repetition and slowness. Second, Attention Restoration Theory (ART) suggests that feedback should avoid tired cognitive patterns such as things related to the everyday environment or complex stimuli that stimulate judgement, and the feedback should be a minimal, soft stimulus where there is an anchor to promote effortless reflection. Finally, Sensorium is a multi-modal neurofeedback system that translates EEG brainwaves to sound and light. A study showed participants had increased bodily and mental awareness after experiencing Sensorium (Hinterberger, 2011).

7.3.2 Neurofeedback and Immersive Environments

In terms of systems that use neurofeedback together with immersive environments, PsychicVR uses VR and EEG neurofeedback on the focused attention aspect of mindfulness meditation. When the user is focused, they are able to make changes in the virtual environment (Amores et al., 2016). Similarly, RelaWorld is a VR and neurofeedback system that provides feedback on a participant's concentration and relaxation. Compared to a control condition (screen), participants had increased attention with both neurofeedback + VR and VR-only. There were no differences between neurofeedback + VR and VR-only (Kosunen et al., 2016). SOLAR is an immersive environment that uses breathing and EEG brainwaves to help novice meditators practice focused attention on breathing. They followed these design principles: thought distancing, abstract visuals, reward system, and Attention Restoration Theory (ART) elements such as nature (Prpa et al., 2015). Finally, one study used gamma frontal asymmetry neurofeedback with the Muse EEG headset in combination with 360 video in an HMD to coach attention back to a positive emotional state (Tarrant and Cope, 2018). Here, the gamma asymmetry threshold is mapped to movement towards a waterfall; if the participant is below the gamma asymmetry threshold, the screen freezes, a red filter appears, and a voice coaches the participant's attention back to a positive emotional state.

7.3.3 Lucid Dreaming Specific Systems

Lucid dreaming has often been viewed as the "ultimate virtual reality" because of the knowledge one is in a non-ordinary reality and at the same time feel like one is there in that reality, and one is able to essentially do whatever they want including live out fantasies that are not possible in waking life (LaBerge, 2000; LaBerge and Rheingold, 1990). Lucid

dreaming is also much like VR because what is experienced in the lucid dream has real world effects both on a person's psychological and behavioural level (Taitz, 2014). For example, one can change the outcome of a nightmare or practice a sport while lucid dreaming, and have that confidence carry over into waking life (Voss et al., 2009). The follow are technological systems that are directly trying to design for dreaming, lucid dreaming, or other altered states of reality.

Inter-Dream is a novel multisensory interactive artistic experience driven by neurofeedback to help with restfulness and sleep-onset (Semertzidis et al., 2019). It uses an HMD and projection as outputs. A mixed methods study found Inter-Dream statistically significantly decreased pre-sleep cognitive arousal, negative emotion, and negative affect. Semertzidis et al. (2019) suggest the following design strategies based on their EEG data and interviews: facilitate exploration, promote neurocentric agency, and facilitate self-expression. Dormio is a targeted dream incubation device that measures muscle control and brain waves (EEG) to detect sleep states and provide extended states of hypnagogia (Haar Horowitz et al., 2018; Horowitz et al., 2020). In a controlled study, researchers found Dormio was able to successfully incubate the auditory prime "tree" in dreams in 67% of participants (Horowitz et al., 2020). Hallucination Machine is a deep-dream neural network immersive 360 video system that simulates the visual hallucinatory experiences in a biologically plausible and ecologically valid way, as evidenced in two experiments (Suzuki et al., 2017). Isness is a multi-person VR journey where participants experience the collective emergence, fluctuation, and dissipation of their bodies as energetic essence, comparable to a psychedelic experience. The design was grounded in six concepts from the literature: matter as energy, connectedness, unity, ego-dissolution, transcendence of space an time, and noetic quality (Glowacki et al., 2020). One of the few neurofeedback systems designed to train for lucid dreaming states found that EEG alpha feedback together with audio and tones had no increase of lucid dreaming frequency (Ogilvie et al., 1982).

Kitson et al. (2018b) conducted a phenomenological study with proficient and active lucid dreamers and derived the following design considerations for immersive environments: sensation and feelings of vividness and clarity; multisensory experience; exploration and sense of possibility; playfulness and childlike qualities; fantastical experiences such as flying; sense of control and agency; ease in and out of VR (seamless transitions); ceremony and rituals; abstract and nature elements. These design considerations have been utilized in several studies involving immersive environments (Kitson et al., 2020; Semertzidis et al., 2020, 2019; Stepanova et al., 2019). Picard-Deland et al. (2020) found that when participants experienced a flying VR game and then took a nap, they reported an increase in flying dreams, lucid control, and emotional intensity. This suggests a connection between what is experienced in VR can transfer over to lucid dreaming. This motivated us to create an immersive experience inspired by lucid dreaming that incorporates neurofeedback of focused attention and MILD techniques of lucid dreaming visualization.

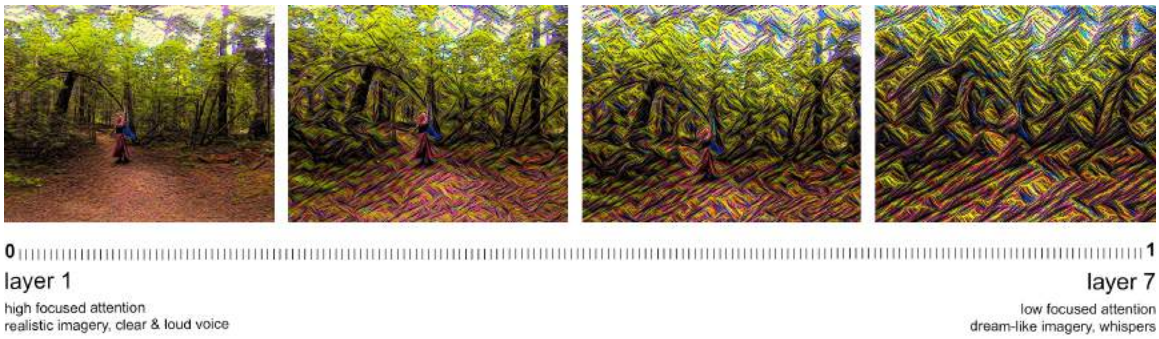

Figure 7.2: Four of seven deep dream layers with their corresponding brain waves score. Layer 1 = high focused attention, realistic imagery, clear and loud voice. Layer 7 = low focused attention, dream-like imagery, whispers.

Band	Range	State
Gamma γ	30-50Hz	hyperactive
Beta β	13-30Hz	alertness
Alpha α	8-13Hz	relaxation
Theta θ	4-8Hz	meditative
Delta δ	0.5-4Hz	deep sleep

Table 7.1: EEG Frequency Band Interpretation (Potter and Bolls, 2012)

7.4 Lucid Loop

7.4.1 Technical System

Lucid Loop is an immersive experience designed to support lucid dreaming practices through neurofeedback of brain waves associated with attention in the form of immersive visuals and audio. Participants wear a Muse 2 EEG headband and an Oculus Quest HMD, where sound emanates from the HMD's built-in speakers. The Muse 2 detects electrical brainwave frequencies that are correlated with certain cognitive states (see Table 7.1). While the accuracy of Muse 2 may be questionable compared to medical grade EEGs (Sawangjai et al., 2019), we selected the Muse 2 because its ease of use and portability. We wanted a consumer product that people could use in their homes and that would also fit with an HMD. The Muse 2's dry electrode placement above the frontal region of the brain is optimally placed to detect brain waves associated with attention (gamma) and it can also sit comfortably underneath an HMD.

We aimed to provide neurofeedback on focused attention specifically, rather than a relaxed or meditative state. Most EEG neurofeedback systems, as we described previously, use alpha or theta band frequencies, particularly in experiences that involve meditation. However, there is evidence that increased gamma activity may be more related to meditation practices particularly involving enhanced perceptual clarity and focused attention (see re-

view: (Lee et al., 2018)). Lucid dreaming is also associated with higher gamma activity over the frontal regions compared to baseline REM sleep (Holzinger et al., 2006; Mota-Rolim et al., 2008; Voss et al., 2009), although Baird et al. (2019a) warns that this correlation could be an artifact of saccadic spike potential. Therefore, research indicates that gamma frequency could be the most similar to a lucid state that we wanted our participants to train.

Muse 2 is comprised of five frontal EEG electrodes including one baseline. Brain waves (uV) are read from EEG electrodes, where a Fast Fourier Transformation then computes the power spectral density of each frequency on each channel. We take the log of the sum of the power spectral density of EEG data over a frequency range (i.e., γ) to calculate the absolute power bands. The mean γ power levels of all EEG electrodes are then normalized to a score between 0 and 1. The score is 0 if <= 20th percentile of the distribution of band powers and 1 if >= 80th percentile.

We use an HMD, Oculus Quest, with six degrees-of-freedom head-tracking to enhance the immersive experiential qualities of lucid dreaming, which we predict will help with MILD technique. The Quest also allows the participant to look around naturally. *Hallucination Machine* used 360 panoramic video with *Deep Dream*, which can give a more realistic simulation (Suzuki et al., 2017); however, we chose a mixed 360 and computer graphics approach to allow real-time modification of specific visual and auditory elements (described below), providing more flexibility for future iterations and control over experimental variables. *Lucid Loop* was created in Unity, with visuals artistically rendered with an enhanced Deep Dream AI system (DiPaola et al., 2018) together with Painterly system (DiPaola, 2017)—a non-photorealistic rendering system that uses algorithmic, particle system and noise modules to generate artistic colour palettes, stroking and styles.

For the mapping, the higher the score, the greater the change in band power. Thus, if a participant is more in the γ frequency, this indicates that focused attention is also increased and the image and audio will become clearer. Likewise, when a participant is less in the γ frequency, then focused attention decreases and the image and audio will become more blurred (see Figure 7.2).

7.4.2 Visual and Auditory Design

In *Lucid Loop*, we aim for visual and auditory effects similar to lucid dreaming, where bizarreness is needed for the dawning of dreaming awareness, but once achieved, the lucid dream scene is relatively realistic (Gackenbach and LaBerge, 2012). We were inspired by research on the phenomenology of lucid dreaming for introspection and VR (Kitson et al., 2018b), which suggests the use of nature, abstraction, clarity, curiosity, and perceived autonomy for VR design. We also took design elements based on the recommendations from HCI researchers who did not look at lucid dreaming per se, but did look at focused attention or other altered states of consciousness. Specifically, Salehzadeh Niksirat et al. (2017)

Figure 7.3: Screen shot of a participant's experience during Lucid Loop, showing the visual design including a painterly aesthetic, vivid colours, particles, a scarf dancer, and a forest environment.

suggest repetition and slowness for focused attention feedback; using the Attention Restorative Theory (ART) dictates that one should avoid complex, everyday stimuli and instead have minimal and soft stimuli. Prpa et al. (2015) also recommend following ART by using abstract visuals and nature elements, as well as a reward system. In terms of simulating an altered state, Glowacki et al. (2020) considers five themes: matter as energy, connectedness, unity, ego-dissolution, transcendence of time and space, and noetic quality.

Given the above design considerations, we developed the following design elements of Lucid Loop (Table 7.2), which are depicted in Figure 7.3.

7.5 Methods

We use a mixed methods convergent parallel approach with both quantitative and qualitative measures. Quantitatively, we use Dream and Lucid Dream Frequency Questionnaire (LDFQ) (Baird et al., 2019b) in order to screen for participants whom are both active and proficient lucid dreamers; Mindful Attention Awareness Scale (MAAS) (Brown and Ryan, 2003) to determine a participant's general tendency and ability to enter into a state of focused awareness (attention). Qualitatively, in a cued-recall debrief method, we used semi-structured interviews while viewing the recorded immersive session to get a more detailed analysis of how participants interact with and experience Lucid Loop as well as to better

Table 7.2: Lucid Loop Design Elements

Design Element	Description	Supporting References
Levels of Abstraction	seven visual layers, each with increasing abstraction of the environment that are mapped to neurofeedback	(Kitson et al., 2018b; Mallett, 2020; Prpa et al., 2015)
Painterly Aesthetic	visually plausible yet bizarre quality to prompt lucidity and support neurofeedback of attention	(Salehzadeh Niksirat et al., 2017; Suzuki et al., 2017)
Vivid Colours	bright and striking colours that can be a focus of attention	(Kitson et al., 2018b; Stocks et al., 2020)
Particles	matter as energy and more feedback on attentive state	(Glowacki et al., 2020; Prpa et al., 2015)
Forest Environment	surrounded by nature as a calm, yet non-everyday environment	(Kitson et al., 2018b; Prpa et al., 2015)
Scarf Dancers	sense of connectedness to others and bizarreness of situation to prompt lucidity	(Glowacki et al., 2020; Salehzadeh Niksirat et al., 2017)
Non-Embodied Self	having no body may result in feelings of ego dissolution	(Glowacki et al., 2020)
Affirmation	MILD mantra of "next time I'm dreaming, I'll remember I'm dreaming"	(LaBerge, 1988; Levitan and LaBerge, 1994)
Whispering	auditory representation of thoughts as a way to support MILD technique	(Prpa et al., 2015)
Looping	repetition of visuals and audio as a trigger for lucidity and supportive means for MILD technique	(Salehzadeh Niksirat et al., 2017)

understand how participants believe neurofeedback and an immersive environment may or may not support lucid dreaming practice.

From a quantitative perspective, researchers are concerned with discovering facts about the phenomenon and assume a fixed and measurable reality. However, the nature of experience, especially attention and user experience, is dynamic and a negotiated reality; this is much better suited to qualitative methods, which are more concerned with understanding human behaviour from the participant's perspective and does not assume a fixed reality (Creswell, 2012). It is very difficult to conduct research relating to felt experience for a variety of reasons, most notably is that felt experience is highly subjective. Most researchers believe the best way to study felt experience is through a combination of different measures in order to approach the construct from multiple perspectives and corroborate results (Patton, 1990). Thus, we used the above measures to corroborate our results. Using qualitative methods to study felt experience, we intended to discover from the participants what kinds of sensations, feelings, and experiences they had during Lucid Loop, as well as what they believe are the strengths and weaknesses of using both neurofeedback and immersive environments to support focused attention and mnemonic induction skills for lucid dreaming practice. We chose not to record brain wave signals from the EEG in order to focus on the felt experience and rich descriptions from participants. In future studies, we plan to include such quantitative measures.

Concurrent methods have the advantage of gathering rich data while the experience is happening, which significantly reduces memory bias that comes from retrospective reports. The drawbacks include being not easily quantifiable, it may not be a comprehensive account, there is a chance of reactivity during the process, and some experiences may not translate well because of temporal and representational limitations of language and translation between thought and experience. However, these methods seem to have good concurrent validity (Patton, 1990). Thinking Out Loud (Watson, 2009) is one method where participants verbally report what they are experiencing while they are experiencing it. This method can be helpful for real-time experiential reports, but can be intrusive or disruptive of the experience while it happens. Cued-recall debrief (Omodei and McLennan, 1994), in contrast, allows the participant to first have the experience while they are recorded from the first person perspective, and then are asked to verbally report their thoughts and feelings while watching the replay. The major advantage of this is not disrupting the experience itself; this is especially important for an experience where disrupting the participant to ask questions would most likely negatively impact the experience, which motivated us to use this method. This method has been used in several HCI and Psychology studies of emotion (Bentley et al., 2005; Bruun et al., 2016; Gao et al., 2012; Quesnel et al., 2018).

7.5.1 Setting

The study took place in a study room at the university or, in one case, remotely from the participant's home. We created a 3m x 3m space in the room dedicated for the immersive experience, so the participant could move around freely without obstacles or wires in the way.

7.5.2 Participants

We recruited 9 participants in total (4 Female and 5 Male), with a median age of 31 years (21-73 years range). The study was approved by the local ethics committee. Our participants were proficient lucid dreamers (N=7) and novice lucid dreamers (N=2), where proficient lucid dreamers have lucid dreams at least once per month (Stumbrys et al., 2015). Glaser and Strauss (1967) recommend the concept of saturation for achieving an appropriate sample size in qualitative studies, so we coded interviews at the same time the data was being collected until we found no new themes or information in the data. To recruit active and proficient lucid dreamers, we followed LaBerge (2014) recommendation. First, verify that informants understand the concept of lucid dreaming by requiring the inclusion of a recognition phrase in a sample lucid dream report. Second, use highly trained participants who are skilful and accurate observers of their conscious experiences. We posted online advertisements on social media groups (e.g., Facebook and Twitter) and lucid dreaming forums. Participants for this study were naïve to this study and did not have prior relationships to us in order to decrease any potential power imbalances and increase the validity of their reports.

7.5.3 Measures

Before beginning the Lucid Loop experience, participants filled out two questionnaires as screening measures. Afterward, participants were asked to describe their experience while watching a first-person recording of their experience in a semi-structured interview.

7.5.3.1 Dream and Lucid Dream Frequency Questionnaire

Proficiency of lucid dreamers was assessed through the Dream and Lucid Dream Frequency Questionnaire (LDFQ) (Baird et al., 2018, 2019b) based on Schredl and Erlacher (2004). LDFQ has high test–retest reliability for both Dream Recall Frequency (r = .85; p = .001; (Schredl and Erlacher, 2004)) and Lucid Dream Frequency (r =.89; p = .001; (Stumbrys et al., 2013)). See supplementary materials for more details.

The **results** from the LDFQ to screen for participants determined that the median number of times participants remembered their dreams per week was 3.5 (*min = 1; max = 6.5)*, and the median frequency of lucid dreams per month was 2.5 (*min = .042; max = 8)*.

7.5.3.2 Mindful Attention Awareness Scale (MAAS)

Mindful Attention Awareness Scale (MAAS), developed by Brown and Ryan (2003), is the mostly widely used mindfulness scale, with an internal consistency of .82, test-retest reliability of 0.81, and adequate convergent and discriminant validity. MAAS measures the general tendency to be attentive to and aware of present moment experience in daily life. It measures mindfulness as a trait that involves two components of consciousness: awareness and attention. See supplementary materials for more details. MAAS has one total score because the researchers believe mindfulness is comprised of many things that cannot be separated out into sub scales. Other scales integrate multiple facets of mindfulness that are not relevant to focused awareness (e.g., FFMQ (Baer et al., 2006)) as it pertains to lucid dreaming, as reported to be a potential issue in Baird et al. (2019b). Therefore, MAAS seems to be the most aligned measure to the construct we are interested in for this study, namely focused awareness (attention).

The **results** of the MAAS in our study showed the median mindfulness score was 3.93 (min = 2.67; max = 4.73), indicating that the majority of participants were generally predisposed to a receptive state of mind in which attention, informed by a sensitive awareness of what is occurring in the present, simply observes what is taking place. But, this was not a strong disposition.

7.5.3.3 Semi-Structured Interviews

Using cued-recall debrief, we screen recorded participants' first-person experiences of Lucid Loop and replayed that immersive experience recording during our interview, which may aid them in remembering their experiences. This screen recording was of the immersive environment only, not the participant's physical body. We used semi-structured interviews that lasted 15-30 minutes. This semi-structured interview protocol consisted of 3-4 broad, open-ended questions as suggested by Glaser and Strauss (1967). We asked participants the following questions, with prompts in square brackets if needed:

- Tell me about your experience with Lucid Loop [walk me through what you just experienced]
- How does Lucid Loop compare to your experience of lucid dreaming? [what are the strengths and weaknesses of Lucid Loop?]
- Tell me about your experience with focusing your awareness [to what extent were you able to control your attention?]
- What (if anything) would you change about Lucid Loop? [what improvements could be made?]

7.5.4 Procedure

After signing an informed consent form, we asked participants to complete an online survey that included demographic information, the LDFQ, and the MAAS. Next, we explained the Lucid Loop experience to participants: the immersive visuals and audio will appear clearer when focused attention is high and will appear less clear when focused attention is low. We asked participants to play with their attention and notice how the experience responds. We also asked participants to be in the moment and simply experience Lucid Loop, since we will screen record their first-person experience and we will talk about it afterward. Participants were told that the experience would be 10 minutes and we would tell them when the time ended, and they could stop at any time without any consequence to the study. They could choose to remain seated or walk around for the experience; a virtual boundary would appear if they were near a wall.

When participants were ready to start the experience, we helped them put on the Muse 2 EEG headset, using the MindMonitor app to ensure all electrodes were connected and the signal was clear. Next, we helped participants fit the Oculus Quest VR headset on top of the Muse 2, being careful not to shift the electrodes. Using the Oculus Touch controllers, participants selected the "Record Video" option, which then began the Lucid Loop experience. We started the timer for 10 minutes, observed the participants, and helped them if needed. After 10 minutes, we helped participants take off the Oculus Quest and Muse 2, which automatically stopped the video recording and saved it to the device. For the semi-structured interview, we showed participants the video recording of what they just experienced and we asked them to walk us through what they thought or felt. After the interview, participants were thanked for their time and to contact us if they had questions or additional insights from experiencing Lucid Loop.

7.5.5 Analysis

We analyzed the questionnaire data (results reported above) to report the descriptive statistics of LDFQ—how often participants remember their dreams and how frequently they have lucid dreams. We also used descriptive statistics with MAAS, which informs us of a participant's tendency and ability to enter into a state of focused attention.

For the semi-structured interviews, we used thematic analysis (TA) to analyze participants responses and explore what they think and feel about our neurofeedback and immersive environment research prototype (Braun and Clarke, 2006). Here, we use TA under the framework of essentialist, which reports experiences, meanings and the reality of participants (Braun and Clarke, 2006). We discussed the themes and their prevalence throughout the analysis to ensure they accurately represented the data. We provided a rich thematic description across the entire data set to give the reader a sense of the predominant or important themes. A detailed and nuanced account of one particular theme, or group of

themes, within the data provides nuance and important detail that may be lost in a thematic description. However, understanding the participant-system interaction and areas for improvement is the primary focus of this study where an overview of all themes is helpful.

Two coders transcribed and coded the interview data in NVivo 12 Qualitative software. We used theoretical/deductive coding in order to get a more detailed analysis of how participants interact with and experience Lucid Loop. Inductive coding would give a more rich and emergent perspective of the data, but theoretical coding seems more appropriate here since we are interested in answering a specific research question. Our prior background and theoretical knowledge is also likely to influence the analysis either way, so a theoretical approach might be more honest. We looked at the level of semantic themes, which involves a progression from description, where the data have simply been organised to show patterns in semantic content, and summarised, to interpretation, where there is an attempt to theorise the significance of the patterns and their broader meanings and implications (Patton, 1990), often in relation to previous literature. These six phases for TA are suggested by Braun and Clarke (2006), although they note that TA is not a linear process, but a recursive process where one moves back and forth through these phases:

- Familiarize yourself with the data;
- Generate Initial codes;
- Search for themes;
- Define and name themes;
- Produce the report.

We had several passes through the data to generate codes. First, each coder separately went through two of the same interviews coding anything related to our research questions, namely mentions of the immersive environment, neurofeedback, and design features. Interesting quotes were also coded. The two coders presented their findings and any differences were discussed. This process was repeated for several rounds until the inter-rater reliability (Cohen's Kappa) was of good (.4 - .75) to excellent (> .75) agreement. Once agreement was met, the two coders coded all of the interviews again (agreement for each code = 80.44-100%). We finished with six higher level codes, each with several sub-codes: dreams, felt experiences, interaction, sounds, visuals, and wants. These codes and their sub-codes, along with their descriptions can be found in our supplementary materials.

After coding the interviews, we created a spreadsheet of all nodes to see where they might overlap. Then, we began looking for themes using strategies recommended by Saldaña (2015). First, each coder made a top 10 list of quotes that they felt were most vivid or representational of the data and reflected on them in different ways, e.g., chronologically and narratively. We referred back to our spreadsheet of overlapping nodes to check whether

our selected quotes were in fact representative of the data. We printed out these quotes for ease of arranging and rearranging, taking photos to document our process. Next, we arranged the combined top 10 quotes in a trinity of concepts in a Venn diagram (based on Soklaridis (2009)). Afterwards, we used codeweaving—the actual integration of key code words and phrases into narrative form to see how our codes and themes fit together. Finally, we went back to the original transcripts of the data to check whether our themes still made sense.

We used member checking to ensure validity of our account of participants' experience. We also identified and analyzed discrepant data and negative cases, discussing our conclusions with each other to identify potential assumptions, biases, and logical flaws. We compared participants' interview responses with their self-reported dream and lucid dreaming frequency and mindfulness scores to see if there were any potential connections.

7.6 Results

We found three major themes from our thematic analysis: relating, discovering, and being there. *Relating* here means participants were connecting their experience with Lucid Loop to their own life experiences, which could be non-dreaming or lucid dreaming; elements in Lucid Loop would remind them of something they had experienced before or they recognized a specific person, place, or feeling. *Discovering* here means participants were figuring out the boundaries of Lucid Loop by playing with the interaction and testing the limits of the system. *Being there* means participants felt like they were an active observant in the experience, noting the feeling of physical presence of objects and people in the immersive environment and at the same time feeling like they were essentially invisible to other actors in the immersive environment. While we discuss these three themes separately, the data (quotes) can overlap two or even all three themes.

7.6.1 Theme 1: Relating

Participants were making connections between their own life experiences and their experience with Lucid Loop. This was often in the form of a comment "that reminded me of X" or using metaphors to describe their experience. The kinds of connections made were quite broad, including connections to art, people they knew, places they had been, altered states of consciousness and dreams they experienced, sounds that reminded them of something, and their own specific lucid dreaming experiences.

7.6.1.1 Relating to Art

While experiencing Lucid Loop, participants would often relate what they experienced to their own waking experiences. The patterns and aesthetic style reminded participants of specific art styles, such as Van Gogh for the brush-like style or Dali for the surrealism: "*It*

sort of reminded me of that animated Van Gogh movie where everything is pastel paint. I really liked that. It was just beautiful to look at." (P02)

7.6.1.2 Relating to People and Places

The setting itself was intriguing to participants, and they would often try to figure out the people's identities and the forest's location. Several participants seemed to have a strong reaction to the male character in the scene, stating that they felt some recognition or had similar physical features to someone they knew: "*He kind of reminded me of a guru guy, like Ram Dass in his older years.*" (P03) For many, the physical surroundings were very familiar to the Pacific Northwest forests and hiking trails they had been to before.

7.6.1.3 Relating to Altered States of Consciousness

The feeling of being in the virtual environment was likened to the movie *The Matrix* because "*how in VR everything is just a perception*" (P01). Similarly, participants likened their experience here to other altered states of consciousness, i.e., non-ordinary states, such as psychedelic trips and meditation:

> *It's kind of like a psychedelic experience where you go into a fear. If you go into a fear thought, it can spiral out of control and and it can be very hard to reel yourself back in. So I've learned even through that to recognize that this is just an experience, it's not going to last forever, it's just trying to show me something. And if I just surrender and relax everything will be ok.* (P03)

7.6.1.4 Relating to Sounds

For the MILD mantra, some participants found it creepy because the repetition felt like brainwashing. At the same time, the repetitive nature of the phrase *"next time I'm dreaming, I'll remember I'm dreaming"* was like participants' lucid dreaming practices of noticing when something feels weird and asking themselves if this is a dream. One participant wondered whether this MILD technique might help them have a lucid dream that night: "*And as I was doing the experience and being in it, I kept hearing that. Well, first off, I'm not in a dream. But then I thought, I kept thinking, this is going to be so interesting like I'm so interested to see what's going to happen tonight. Will things be more vivid or what?*" (P04).

7.6.1.5 Relating to Dreams

Often, participants would compare Lucid Loop to their own dreaming experiences. In some instances, this comparison related to both the visual styles and clarity of Lucid Loop and both lucid and non-lucid dreams. For about half of the participants, they found aspects to be very much like their own dreaming experiences, with the aesthetic style evoking a more dream-like visual experience: "*The blurriness, the colour, and difficulties too to focus*

on things I found well done. I think it comes close to my experiences." (P07). Specifically, the fluidity of people and objects melding into one another, having people in the scene, and the nature elements were all reported to be like some participant's lucid dreams. The other half wanted Lucid Loop to look more realistic to better match their own dreaming experiences: "*When I'm in a dream it looks like real life, it's more like me looking at you. But being in this experience, like I said, I feel like I'm in a cartoon. And when I'm in a lucid dream, I'd love to be in a cartoon actually, but it's never happened to me. So, I think it's too fantasy-like.*" (P06)

7.6.1.6 Relating to Lucid Dreaming

Participants also made connections to their lucid dreaming experiences and their use of induction techniques such as reality checks. In Lucid Loop, they found they were unable to look to their hands to check their fingers, and they could not change or interact with the scene like they would in a lucid dream: "*Being able to move to a different environment would be to me one thing that would be important because it's very characteristic of at least the lucid dreams I have... The idea of, for me, lucidity always involves moving somewhere else.*" (P08)

For some participants, the emotional feeling rather than the exact visuals and sounds were more important to lucid dreaming and that Lucid Loop seemed to evoke an emotional response; even though this emotional response might be negative. For example, participants felt the experience was at times claustrophobic, dissociating, frustrating, or boring:

> *I have had dreams where there are spiralling patterns, but that was like a nightmare if I'm being honest. Which is actually what started my lucid dreams. I stared having these sorts of experiences in a normal dream and thought well this isn't a pleasant experience so I'll just change it.* (P09)

Although, overall, participants thought the experience was enjoyable, magical, beautiful, and mesmerizing: "*The very top shape looks like a flower and at the bottom near my feet was also like that, and I thought that shape, that flower shape, it's like mesmerizing, you could look at it for a long time.*" (P04)

7.6.2 Theme 2: Discovering

Participants were discovering the boundaries, interactions, and limitations of the system by using specific techniques and observing how that changed the experience. They were also noticing how the experience sometimes did not react in a way they anticipated or hoped for; sometimes questioning the accuracy of the equipment, the system, their own experience, and even their own mental state.

7.6.2.1 Discovering Degree of Control

Many participants felt some degree of control over how they influenced the system, although many questioned their psychological state and whether that was accurately reflected in what they experienced. This was sometimes a question of the responsiveness of the EEG: "*Maybe it takes training. Maybe I didn't plug into the means of influencing it properly. Maybe I should do something else. I think it requires more experimenting, like more than 10-15 minutes.*" (P07) This sense of control seemed to be tied closely with participant's sense of agency or feeling like they had the means to act independently; the more barriers participants ran up against, the less agency they seemed to have.

7.6.2.2 Discovering Boundaries

When participants could not control the Lucid Loop experience or shift the visuals and sounds like they could in their own lucid dreams, they were discovering the boundaries of the system:

> *I was confused at first, like I was trying to figure out what it's meant to be, if there is such a thing. You can completely distort it like you can in a lucid dream, but in a fixed environment. Like I thought you could change the colours of the objects, so I tried to do that for a while and I figured out that was not going to happen. So, I just moved my focus on wards.* (P09)

The neurofeedback seemed to work as participants expected, yet at the same time participants expected more interaction or rather did not yet have the attention regulation skills to change the virtual environment as they wished.

7.6.2.3 Discovering Interaction Techniques

Participants would play with different interaction techniques in order to see how they could influence the neurofeedback system using the EEG, but also to understand the limits of their agency over the system. These techniques included variations on mindfulness meditations, looking in certain directions, or focusing their attention on a specific object like the ground, sky, and trees. The general pattern, or visual aesthetic, was something participants focused on and they observed how the patterns changed with their attentive state:

> *I was going from a landscape that was pretty defined and then as I focused or concentrated, everything started zooming in onto the patterns and they got larger, louder, the voices were louder. And I thought that was cool because I actually tried to do that and got that feedback. So, that was really cool; it was very confirming like ok this is change in my mental state when I'm flexing this muscle. And then my intention was like how much can I flex? How much can I focus and concentrate?* (P02)

Mostly, though, participants looked at the moving elements of the scene, especially the people: "*I feel like I just observed those thoughts and it took a while to focus on the dancer. And I feel like there was a part of me, especially when the dancer was really abstract, that was really inspired by the movements.*" (P05)

7.6.2.4 Discovering Limitations

While participants felt Lucid Loop was in general a "cool" and "interesting" experience that they see the potential for training lucid dreaming, there were still some limitations. Participants felt they wanted to be able to interact with the space more by physically moving around, changing the scene, and talking with the characters. Specifically, in relating to their lucid dreams, the scene itself was a good start, but because participants could not move on to the next scene they felt stuck and the experience felt less like a lucid dream: "*I would say being able to move to a different environment would be to me one thing that would be important because it's very characteristic of at least the lucid dreams I have.*" (P08) Participants noticed that both the scenery elements and one of the virtual characters seemed to be hinting at the potential for moving down the virtual path. They expressed a desire to go down the path, even though eventually they discovered this was not possible: "*I just wanted to go with him down the path. I think I stood up relatively soon after this because I wanted to try and follow him as opposed to thinking about following him in my head. I felt like I needed to stand up for some reason to try and go.*" (P03)

7.6.3 Theme 3: "Being There"

Participants often commented on their sense of feeling like they were in the virtual environment, as well as relating to the feeling of being with other people and objects. For example, sensing the scale of the environment, wanting to reach out and touch virtual objects or people, and passively interacting with the virtual people. Participants felt they were physically there in Lucid Loop's virtual environment because of the visual and auditory immersive properties. Yet, they also psychologically knew they were simultaneously in two realities. We use the term "being there" instead of "presence" because the former term captures more of what participants described in their interview and the latter means something more specific in the VR literature (Slater, 2003).

7.6.3.1 Being There as Self

One of the main points participants brought up was that their expectation was for the experiences to feel more like a lucid dream. Participants felt Lucid Loop was physically immersive and stimulating, yet they did not feel physically present because they could not see their body or hands to perform their usual reality checks: "*I thought you'd be able to see your hand. The thing is, for me in lucid dreams, my fingers are my means of what triggers I*

am in a dream. With that, I couldn't look at my hands and it didn't help." (P09) This sense of disembodiment was disorienting for some, while for others it was an interesting novelty that they wanted to explore more. One participant tried focusing on their body even though they could not physically see it.

7.6.3.2 Being There with Others

Participants also felt like the characters did not acknowledge their social presence as they usually would in lucid dreams. So, participants felt they were physically with the characters and nature elements, but it was more like they were ghosts witnessing an event take place with minimal influence: "*I was trying to touch them and I was like the invisible one there in that experience.*" (P01)

7.6.3.3 Being There with Objects

Participants felt sensorily immersed in the virtual setting of Lucid Loop. And, that sense of being there with different nature elements, such as trees and particles, helped support the feeling of perceived agency: "*I like the aspect that you're in the brush physically and that does something for your agency in the scene, which is ultimately what gets you to lucid dreaming.*" (P07) As P07 points out, a sense of agency and control is important for lucid dreaming, even if one chooses not to act and simply observes. It seemed like the trees especially helped support the feeling of being there because participants could look up and feel the scale of the environment, and also the light shining through the trees gave participants something to focus their attention on and was likened to a technique used to prolong lucidity: "*If I looked up, it should be in the last two minutes, there should be a spot if I just looked at that it just brought the entire screen back into focus. Which, to be fair, is quite normal in lucid dreaming. If you look up, it does help.*" (P09)

7.6.3.4 Being There with Sounds

In terms of the audio in Lucid Loop, participants felt that the repeating MILD mantra and the lack of any other sounds was not enough to support them feeling like they were in the dream scene. Instead, they suggested adding more nature sounds and sound effects in addition to the voice to enhance the feeling of being there: "*They have like a scarf that they're moving something, like the sounds of how you move or sounds of how you walk along a trail, footsteps, and the wind, or birds. So, those audio will make it more real... not real, but hard to judge that I'm in a virtual reality.*" (P01)

7.6.3.5 Being There as a Dream State

Some participants likened the experience to a dream state because they had an awareness that what they were seeing and hearing was not in fact ordinary reality and at the same time reacting to the environment as if it were not virtually present:

> *So, it kind of resembled that state when I'm waking up in the morning. I know what's going on but I also know this is a dream. So, it kind of felt like that particular stage when you're about to get up in the morning and you're aware of your surroundings but you're still dreaming.* (P01)

One participant even went so far as to distinguish how Lucid Loop compared to both lucid and non-lucid dreams, namely the sensory immersiveness and awareness aspects:

> *It is immersive and you are experiencing something you wouldn't experience without it, but at the same time, you still know that you are awake, but you don't know you're awake when you're dreaming unless you're lucid. So, I think that's the distinction for me for what I've experienced here and what I experience when I'm actually dreaming, Because there isn't an awareness unless you become aware.* (P06)

The varying levels of abstraction was one aspect of Lucid Loop that contributed to this sense of non-ordinary reality. While they might not exactly match the visuals of a person's own dreams, these patterns and changing levels of abstraction were parallel to participants' recollection of visuals in their lucid dreams: "*I think when I remember dreams in general but also my lucid dreams, the spatial and physical memories are very fluid, which is not like the real world. And having that fluidity, this captured that fluidity really well of people melding into patterns and other things.*" (P02)

7.7 Discussion

7.7.1 Comparison of Lucid Loop to Lucid Dreaming

One of our main research questions asks in what ways are lucid dreaming and immersive environments alike and dissimilar? We discuss in this section the similarities, dissimilarities, and more nuanced results based on the interview responses from proficient lucid dreamers who tried our immersive experience.

7.7.1.1 Similarities

In terms of similarities, one of the most prominent features similar to lucid dreaming was **focused attention**. Specifically, participants mentioned that it was helpful to have different things to focus on and see them change with neurofeedback, such as the people moving,

spiraling patterns on the ground and sky, and recognizable trees. Moreover, there were few elements in the virtual scene, which helped participants to focus their attention on one or two things rather than be overwhelmed with many elements. The fact that participants were wearing an immersive HMD also helped them to focus their attention because they were not distracted by whatever was happening outside the immersive environment. Finally, the focused attention neurofeedback seemed to work as expected. When participants tried to focus their attention, they noticed a change in the scene and audio. Focused attention is an established technique to improve lucidity (Stumbrys and Erlacher, 2017; Stumbrys et al., 2015; Wallace and Hodel, 2012). In this experience, participants found Lucid Loop was able to similarly support focused attention through the HMD's immersive qualities and ability to highly customize the environment with points of focus that were not distracting.

The second similarity to lucid dreaming was the concept of **fluidity**. Participants felt that the patterns and people melding into one another closely mirrored their experiences with lucid dreaming. This was helpful as a way to visualize becoming lucid or practicing the MILD technique. This finding is congruent with ART, which states that complex stimuli, such as a room or urban space, can be too distracting and that a soft stimuli is better suited to support effortless reflection (Salehzadeh Niksirat et al., 2017). Both Lucid Loop and lucid dreaming seem to support qualities of fluidity because of the less bounded nature of their realities.

The third similarity to lucid dreaming was in the feeling or the **emotional reaction** to the experience rather than the environmental richness. That is, participants had a distinct emotional response, be it positive or negative, to the immersive experience even if the exact visuals or audio was unlike their typical lucid dreams. Dreaming experience has been linked to emotional processes (Scarpelli et al., 2019), so having an emotional response in immersive environments is perhaps similar to the functional role of dreaming in emotional processes. An EEG study showed that gamma activity is not only related to emotional processes and dream recall but it is also correlated to lucid dreams (Voss et al., 2014). There seems to be some evidence that lucid dreaming is tied to emotional processing, and Lucid Loop here appears to afford unique qualities that may support emotional experience. Therefore, both Lucid Loop and lucid dreaming appear to share the capacity for emotionality.

The fourth similarity to lucid dreaming was in the **techniques to maintain lucidity**. Specifically, participants mentioned the people spinning and looking up at trees or sky were similar techniques to maintaining lucidity. This finding seems consistent with lucid dreaming guides that suggest spinning during a dream will prolong the lucid dream state compared to "just going with the flow" (LaBerge, 2009). One participant even thought about spinning themselves, but decided against it because they did not want to fall over while wearing the HMD.

Finally, the fifth similarity to lucid dreaming was in **questioning reality**. Specifically, participants were continuously questioning different aspects of the Lucid Loop experience

such as their own mental state, the visuals, the EEG's accuracy, who they were, who the people were, and where they were. This is similar to lucid dreaming practices of questioning whether you are in a dream or not (Neuhäusler et al., 2018). For example, lucid dreamers are trained to look for peculiar events in their day to day life and, when one occurs, to ask themselves if they are dreaming and maybe perform some reality check (Tholey, 1983).

7.7.1.2 Differences

While there are several similarities between lucid dreaming and Lucid Loop, we also found differences that could point to the current limitations of immersive technology. First, almost all participants found **reality checks** were lacking in Lucid Loop. That is, they were not able to see their hands, look at the time, read a piece of paper, or fly. All of these listed reality checks are something lucid dreamers usually do to confirm whether they are dreaming or not (LaBerge and Rheingold, 1990). Something we could incorporate now to simulate these reality checks could be adding hand tracking and some semblance of a body, a time piece or text that changes oddly each time you look at it, and some flying-like locomotion.

The second difference was in the **people interaction**. In lucid dreams, participants reported that they are the center of attention and people are looking at and interacting with them. In this 360 experience, the people are pre-recorded so they do not respond to the participant directly. Furthermore, in lucid dreams, participants are able to ask people questions and talk with them, but that is limited here. Two possible solutions could be to implement a multi-user immersive system to have real-time interactions with others or make use of virtual agents that appear to react to the participant in a more natural way.

The third difference was the extent of the **multisensory experience**. In lucid dreams, some people (not all) will have a wide range of sensations such as haptics, smell, taste, and wetness, in addition to audio and visual components. Current immersive technology simply can not recreate all senses to the extent we experience them in ordinary reality. However, we could include the latest immersive technology that at least tries to recreate some of the experiences of smell, haptics, taste, and temperature (e.g., (Harley et al., 2018)).

The fourth difference was in **controlability**. For most lucid dreamers, they can get to a point where they can do whatever they want and change whatever they want at any moment. In immersive experiences, this has to be programmed and it is very challenging to account for every possible interaction a participant may want. The closest possible solution is to utilize brain-computer interfaces (BCI) that might be able to differentiate between different brain states and change the immersive environment accordingly. Although BCI is increasingly used in HCI and artistic applications (Prpa and Pasquier, 2019; Yadav et al., 2020), presently no such BCI exists that can directly read our thoughts.

7.7.1.3 Mixed

We found that there were mixed views on some aspects of Lucid Loop when comparing it to a lucid dream. Here, we find more subtleties when comparing lucid dreams and Lucid Loop. The first was in MILD technique's **lucid affirmations**, which are usually present or future tense statements that are designed to train thought patterns that will carry over from waking to dream state, e.g., I am fully aware of when I am dreaming. In Lucid Loop, the affirmation is present as a looping audio of "next time I'm dreaming, I'll remember I'm dreaming". However, participants are not voicing this affirmation themselves. Rather, the audio affirmation acts as a cue for which the participant may or may not engage with. Some participants felt the affirmation was more like brainwashing rather than a cue for practicing dream awareness. It is unclear whether the benefits are in saying the affirmation yourself or if listening to the audio alone is sufficient. One recent study showed that the number one strategy for lucid dream control was verbal (Lemyre et al., 2020), which may or may not correlate with verbal affirmations in waking reality. One way to further explore this could be adding a microphone component so that participants can voice their own affirmation; and we might even record and replay that affirmation back to the participant for added personalization.

Another component of Lucid Loop that had mixed comparisons to lucid dreaming was in MILD technique's **dream visualizations**. For one, colours for some were too bright and neon but for others it mimicked their dream experience. For another, the general ideas of fluidity and bizarreness were like lucid dreams, but the actual patterns were perhaps too abstract and cartoon-like. Lucid dreamers find the bizarreness comes from changes in ordinary perception rather than starting with a bizarre situation (Kitson et al., 2018b; Mallett, 2020). The abstractness helps in terms of supporting narrative and questioning what you are experiencing, which is central to lucid dreaming practice. And at the same time, participants felt too far removed from ordinary reality. Perhaps the "trippiness" in lucid dreams comes from non-visual elements like movement or a feeling. We could incorporate aspects for movement or even flying, tone down the abstraction layers or have more subtle changes for specific parts of the experience, i.e., only certain elements in the scene change like the trees or the sky.

Nature elements, such as trees, were another aspect that some participants never dream, while others felt was very much like their lucid dreams, even if not a forest but an open field or a cave or mountains. Participants also felt Lucid Loop was a bit sparse for animals since normally in their lucid dreams there would be animals if the dream setting were in nature. We might try adding in more of these nature elements to round out the experience, though it is worth noting that too much stimuli in the scene could take away from the main intent (Salehzadeh Niksirat et al., 2017), which is to practice focused attention.

Another component that was not quite like lucid dreaming was the **lack of scene change**. While some participants felt Lucid Loop could be one instance of a lucid dream or that the pattern abstraction layers could be like a scene shift, the majority of participants wanted more distinctly different scene changes. One of the most common requests was to at least be able to go down the path, like they would normally in a lucid dream. Participants found limitations in movement to be most unlike lucid dreams where they can go as they please. One way to explore this idea in VR could be to slowly morph one scene into another in an ambient-video style, e.g., (Bizzocchi, 2006). And, like we mentioned before, having participants have some control of locomotion so they can explore more of the immersive space without being constrained to one place.

One final aspect of Lucid Loop that had mixed feedback was **agency**. There was some sense of being able to control the environment, but participants quickly found the boundaries of the neurofeedback system. The immersive properties of the experience helped to create some sense of agency or feeling of being there, yet at the same time participants could not control the immersive environment to the same extent they would in a lucid dream. However, research suggests that dream control varies greatly amongst even proficient lucid dreamers (Lemyre et al., 2020). Besides, neurofeedback is not explicitly about controlling your brain waves but rather noticing how they change. To give participants more control, we could add in more interactive elements like hand tracking, the ability to pick up some objects, and have the virtual characters respond more to the participant, e.g., the use of eye tracking to meet their gaze.

7.7.2 Design Features

In this study, we explored how neurofeedback and an immersive environment might support lucid dreaming practice, including a comparison between Lucid Loop and lucid dreaming. In doing so, we hope to identify features to design immersive experiences that promote practices of focused attention (neurofeedback) and mnemonic induction (MILD), which are central components to obtaining lucidity. We relate back to our initial design elements of Lucid Loop listed in Table 7.2.

7.7.2.1 Allude to Experiences of Dreaming

Participants emphasized the importance of hinting at dream-like qualities in order to create a virtual environment they could use to "imagine" becoming lucid using the MILD technique. One of the aspects participants commented on the most was the visual pattern, specifically how their attention changed the clarity of the visuals. The mapping of attention to clarity (LEVELS OF ABSTRACTION) seemed to work well here because it was a conscious pathway of focusing that also mapped well to participants' actual experiences of lucid dreaming. Using a PAINTERLY AESTHETIC with generic or ambiguous visuals worked well because there was enough detail to see the setting and people while at the same

time allowing space for participants to put their own narrative to it—a sort-of Rorschach test. Besides, it is computationally infeasible to personalize the dream setting and people to a level of personalization that would normally be experienced in a dream. A nature setting, like the FOREST ENVIRONMENT, fit here because it was not so familiar yet a setting one would recognize. Other dream-like qualities included the blurring and fluidity of the visual aesthetic, which related to LEVELS OF ABSTRACTION and PAINTERLY AESTHETIC. Most participants felt that fluid quality captured the feeling of dreaming, even if the exact visuals were not something they normally experience. Importantly, it was the noetic qualities of the experience that helped participants to feel like this was a similar experience to lucid dreaming. Since dreaming is related to emotional memory processing (for review see: Levin and Nielsen (2009)), participants felt it was necessary to have an immersive experience evoke emotion.

7.7.2.2 Reality Checks

All participants felt it was important to have reality checks as part of lucid dreaming training, a common induction technique in visual induction of lucid dreams (VILD). One element of Lucid Loop that a few participants picked up on was the repeating or LOOPING video, which could be used as a reality check because in waking reality events do not repeat in exactly the same way. Another element for reality checking is the NON-EMBODIED SELF, or absence of a body, in Lucid Loop. Participants expected some other forms of reality checking in the immersive experience. In fact, many participants thought an immersive environment was a perfect medium in which to do reality checks because you can program an experience to be unlike reality. For example, a common reality check for lucid dreaming is to look at your hands to check whether there are any missing or extra fingers (Neuhäusler et al., 2018). This could be achieved through hand tracking and programming in this feature of changing the number of digits on your hand. Other types of reality checks that are possible for VR include the ability to fly or having a clock or piece of writing change in unexpected ways. The main point is to have an environment that is what one expects in waking reality and then include some aspects that play with expectations of reality and perhaps allow one to do things they would not normally be able to do.

7.7.2.3 Points of Focus

In order to support regulation of attention during lucid dreaming, most participants suggested a few points of focus that are helpful in the context of neurofeedback. Here, the FOREST ENVIRONMENT worked well because there was not too much happening visually, opposed to an urban setting, which allowed participants to find objects to anchor their attention (Salehzadeh Niksirat et al., 2017). This occurred even in states of low attention when the visuals and audio had low clarity. Participants would find the VIVID COLOURS or outlines of movement from the SCARF DANCERS as points of focus. Similarly, in states

of high attention with high clarity in the visuals, participants focused on the points of light of the PARTICLES, the ground, the sky, the FOREST ENVIRONMENT, and especially the movements of the SCARF DANCERS. As one participant remarked, it is easy to focus when there is little distraction. This point underlines related practices of attention regulation, such as mindfulness meditation, where anything in conscious experience can become a point of focus but it is easier, especially for beginners, when the potential points of focus are more limited (Salehzadeh Niksirat et al., 2017).

7.7.2.4 People in the Scene

One of our main findings for supporting a virtual environment that could be used to practice the MILD technique was the importance of having people in the scene, in this case the SCARF DANCERS. Since humans are social beings, our social connections and relationships are one of the most basic needs. Given this fact, it is perhaps unsurprising that we also frequently dream about people and our interactions with others (Schmidt et al., 2014). Likewise, participants remarked that having people in the virtual space supported the feeling of being in the scene and was similar in feeling to a dreaming experience, so they could better visualize themselves becoming lucid. To take the feeling of being there with people further, participants hoped for more interaction with the people and more acknowledgement from virtual others to their presence.

7.7.2.5 Gamma as Feedback for Focused Attention

Prior work alluded to the significant role that gamma brain waves play for both focused attention (Lutz et al., 2004; Travis and Shear, 2010) and lucid dreaming (Holzinger et al., 2006; Mota-Rolim et al., 2008; Voss et al., 2009). Based on this, we sought to determine whether gamma wave feedback might be feasible for training focused attention through neurofeedback. We found that participants thought the visual and auditory clarity neurofeedback from playing with their attention reacted in an expected way. Participants noted in their interviews that seeing how they could influence the clarity of the images and audio was exciting in itself, and the constantly changing artistic visuals was a motivating factor in practicing focused attention. These comments are highly promising for the potential for using gamma brain waves as neurofeedback for focused attention. However, we are cautious in recommending the use of gamma neurofeedback for focused attention since there is still little evidence for its efficacy and much more research is needed to find a definitive answer (Baird et al., 2019a). We did find that participants who tried other techniques besides focused attention—such as open monitoring meditation, relaxation, and overthinking—were unsuccessful in trying to change the visuals and audio in the way they wanted. This suggests that focused attention may be a distinct state from related concepts such as mindfulness, relaxation, and anxious thinking.

7.7.2.6 HMD Immersive Environments

Immersive environments, specially the head-mounted display kind that completely immerses your visual and auditory senses, was a crucial component in promoting mnemonic induction practices of lucid dreaming (MILD). First, participants had the simultaneous feeling like they were in the virtual space and also in the ordinary reality space. This is exactly like lucid dreaming where the dreamer has the feeling of physically being there in a dream and at the same time knowing they are in fact sleeping in waking reality. Secondly, one participant pointed out that in lucid dreaming a sense of agency is important because you know you can potentially control any aspect off the dream once you realize you are in one. In the same way, immersive environments support a heightened awareness of one's surroundings because of its immersive properties, so that one has the feeling that anything is possible—it is virtual after all, so the possibilities are limited only to the computer program.

7.7.3 Other Considerations for Designing Immersive Experiences for Lucid Dreaming Practice

Besides the design features we put forth above, we want to expand on some other considerations we feel are important for designing a immersive experience that supports lucid dreaming practice. Some of these considerations are in opposition to what our participants wanted to see, but we feel it is important to listen not only to what is said explicitly but also understand the core motivations behind their feedback.

7.7.3.1 Control/Wanting More

One of the main themes from the interviews was that participants wanted more control and interactions with the environment, similar to what they would expect in an actual lucid dream. While we agree that one of the benefits of our system is having a space to practice that is like a lucid dream, we argue that it need not be exactly like a lucid dream. While there are some works in HCI that look at creating simulations of experiences, such as psychedelic hallucinations (Suzuki et al., 2017), we are more interested here in providing an experience that supports a practice rather than a simulation. While both are relevant, we feel it is important to distinguish between the two because we are not trying to emulate lucid dreaming, rather we are attempting to provide another tool for the practice itself. One of those tools was neurofeedback of focused attention. This is one form of control, although neurofeedback is not about control per se. Participants can use their focus to "control" the visuals and audio in the immersive environment, although this is not how we designed the mapping. Instead of this one-to-one mapping where participants want to control their environment, we wonder if mapping multiple aspects of focused attention to different elements in the scene might promote a practice of noticing rather than controlling.

7.7.3.2 Being There with People

The most important themes participants brought up were a sense of agency and feeling like they were there (non-embodied self); especially feeling like they were there with other people, not simply having people there visually but also a sense of another there with them. In designing for that feeling of being there with others in a way that emulates lucid dreaming, a multi-user experience rather than a pre-recorded video of people might be more impactful. Here, participants would be able to reach out and interact with each other in real-time and, in doing so, create a greater sense of being in the immersive environment with others, like a shared dream.

7.7.3.3 Audio

Audio is perhaps one of the more neglected aspects of an immersive experience, yet it is one of the most important aspects in world building and increasing immersion (Schütze and Irwin-Schütze, 2018). Participants felt there was a distinct lack of sounds, especially background noise and nature sounds. Something not mentioned by participants was the fact that the repeating voice (looping, whispering, and affirmation) was a lucid dreaming technique that is normally voiced by yourself. We wonder if participants were encouraged to voice the mantra "next time I'm dreaming, I'll remember I'm dreaming" might be more powerful in terms of lucid dreaming practice, specifically mnemonic induction, rather than simply hearing the voice of another. However, more research is needed in determining whether this techniques for lucid dreaming is more efficacious through oral or aural channels.

7.7.3.4 Narrative Elements and Perceived Agency

The narrative elements of Lucid Loop (e.g., the moving, costumed characters and the setting of the path in the woods) were not part of a plot or narrative arch nor were they interactive. Participants could not speak with the characters or navigate the environment, but these elements still allowed for a level of cognitive interactivity with the system in which participants can have an emotional or psychological response even without being able to change those aspects of the experience (Ryan, 1999; Zimmerman, 2004). The level of artistic abstract rather than unprocessed 360 video footage also enabled participants to imagine familiar people or places.

7.7.4 Limitations and Future Work

Our first research question compared the experiences of lucid dreaming and Lucid Loop. We found many similarities, but also some limitations within the technology. More work is needed in understanding the differences and similarities at a level of conscious experience, and the potential outcomes.

Our second research question sought to understand whether it is possible to design a neurofeedback and an immersive experience to support lucid dreaming practice. We have found that the answer is a tentative yes, but with many more questions still to be answered. Based on the study presented in this paper, we do not know definitively whether our system in fact increases lucid dreaming frequency or duration, nor can we say that the training was effective. Future work would look to improve upon our system or use our design considerations with a new immersive-neurofeedback experience in order to determine their efficacy. Moreover, future studies might involve a more controlled setting where researchers can measure whether a participant has had a lucid dream through eye tracking, a battery of validated questionnaires, and interviews. While our first qualitative study here paves the way forward in better understanding the potential of this technology for supporting lucid dreaming practices, there is still much work to be done in narrowing down the precise mechanisms and design choices.

7.8 Conclusion

The practice of lucid dreaming has shown significant benefits for mental well-being, including enhanced attention regulation and positive emotions such as love and awe. However, there is a significant barrier to having lucid dreams because we cannot yet directly share dreaming experiences that might help lucid dreaming novices better learn. Instead, we rely on written and auditory guides. Furthermore, while there are parallels between lucid dreaming and immersive environments as well as potential for neurofeedback in training focused awareness, the connection between the domains of lucid dreaming, focused attention, neurofeedback, and immersive environments are neither well understood nor well researched. In this paper we described a system that provides real-time feedback on two central practices related to lucid dreaming, mnemonic induction and focused attention, in the form of a neurofeedback and immersive environment system. Reports from proficient lucid dreamers who tried the system felt there were many similarities between Lucid Loop and lucid dreaming, and that such a system would be helpful to novices in practicing both lucid dreaming MILD techniques and focused attention through neurofeedback. We found three major themes that were important for designing a system for supporting lucid dreaming practices: relating, discovering, and being there. These results translated to six major design features: allude to experiences of dreaming, reality checks, points of focus, people in the scene, gamma as feedback for focused attention, and HMD immersive environments. It appears possible for neurofeedback and immersive technology to help support lucid dreaming practices because of their close affinity to existing practices and the dreaming experience. Future work will determine the exact mechanisms for supporting lucid dreaming as well as formally measure the frequency and duration of lucid dreaming after experiencing a neurofeedback and immersive experience such as we have designed here.

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7.10 Author Contributions

AK, RM, SD and BR conceived the main idea of the article. AK designed and conducted the interview study with consultation from RM, SD, and BR. AK and RM conducted co-wrote the analysis. AK completed the first draft of the manuscript with suggestions from RM, while SD and BR supervised the entire work. All authors contributed to the manuscript, read, and approved the final version.

Chapter 8

Discussion and Conclusion

This thesis contributes to both Psychology and Human-Computer Interaction research. Our approach in working on a topic that is still largely unexplored, shroud in skepticism, and at times misunderstood is two-fold. First, we focused on describing self-transcendence from a conceptual, phenomenological and physiological (and neuro-physiological) point of view. We went deep into the evaluation methods for investigating self-transcendence, exploring related concepts and respective assessments methods, e.g., mindfulness, flow, peak experiences, and altered states of consciousness. Moreover, we explained the neurological bases of self-transcendence and related imaging methods. The multidisciplinary and multilevel analysis of self-transcendence as a phenomenon provides a significant contribution to Psychology by providing an extensive overview on methods for measuring self-transcendence. While this work does not directly speak to design work in HCI on self-transcendence, it was essential to have a firm understanding of the phenomenon of interest as well as knowledge for how to evaluate for it. Second, we focused on understanding the design space by both reviewing and designing immersive experiences for supporting self-transcendence. This two-pronged approach allowed us to simultaneously examine the underlying design features of existing work and inductively derive our own design considerations. The final result is a set of insights for designing for self-transcendence in immersive environments that emerged from exploring lucid dreaming as a lens into altered forms of reality that can enact states of self-transcendence. In this final chapter, I revisit the research questions put forth in the Introduction. Next, I discuss key insights that emerged from creating and evaluating two different immersive experiences for supporting self-transcendence. In the context of these insights, I provide some suggestions for future work and speculate on the potential for self-transcendence and immersive technology.

8.1 Revisiting Research Questions

8.1.1 RQ1: How is Self-transcendence Conceptualized and Measured in Different Research Contexts

In Chapter 1, we detailed the different theories of self-transcendence in three broad categories: conceptual, phenomenological, and physiological. Conceptually, self-transcendence in the Psychology domain has been defined as a way of being through fulfilling our personal potential (Frankl, 1966; Maslow, 1969); as a personality trait that captures feeling at one with the universe (Cloninger et al., 1993; Levenson et al., 2005; Tornstam, 1994); a multidimensional model of meditation (Dorjee, 2016; Schoenberg and Vago, 2019; Vago and Silbersweig, 2012) or altered self-consciousness (Millière et al., 2018); and a developmental capacity to expand self-boundaries in a variety of ways (Reed, 2013). Phenomenologically, self-transcendence has been described as a very physical, expansive change in self-boundaries, egolessness and timelessness that can also result in positive affective states, such as joy, love, compassion, forgiveness, wonder, and freedom (Garcia-Romeu et al., 2015). Similarly, others have described self-transcendence as the feeling of the self and world are merged into a unified whole or the boundaries of the self are dissolved, sometimes referred to as non-dual awareness (Josipovic, 2019; Metzinger, 2020; Nour et al., 2016; Yaden et al., 2017a). Physiologically, several studies point to the involvement of the default mode network in the experience of self-transcendence, specifically a decrease in its activity. Self-transcendence is related to an activation of the prefrontal cortex and thalamus, leading to a block in signal to the parietal lobe, which is involved in proprioception and self-other boundaries (reviews see (Newberg, 2014; Newberg and Yaden, 2018)). Self-transcendence has also been related to activations of the vagus nerve via oxytocin and vasopression, which can lead to the feeling of connectedness (review see (Yaden et al., 2017b)).

We searched the literature for different methods of measuring self-transcendence even if they were only proxy measures. We found five major categories of methods: questionnaires and surveys (N=36), diary and journal entries (N=3), interviews (N=6), neurological and physiological measures (N=13), and behavioural measures (N=5). We recommended a set of methods to study self-transcendence depending on the conceptual model of the research. Overall, though, we stressed the importance of of a mixed-methods approach in order to embrace the enactive quality of self-transcendence with empirical rigour.

8.1.2 RQ2: Do Immersive Environments Support States of Self-transcendence and, If So, How?

Designing for self-transcendence is a topic in Human-Computer Interaction (HCI) of increasing interest and relevance given the growing need for technology that respects and supports our mental and physical well-being. Yet, despite its popularity, there is no unified approach for how to design technology-mediated experiences that provide the conditions

to support self-transcendence. There exists a challenge in trying to integrate all the existing knowledge across the various domains because they are using different terminology, frameworks, and theoretical lenses to approach the same topic. In order to address this challenge and answer RQ2, we conducted a scoping review of existing immersive systems that support positive experiences such as self-transcendence (see Chapter 2). We found that the 33 experiences we reviewed were entangled in many different ideological frameworks including Anthropology-Based Computing (Brown, 2013); Techno-spiritual Design (Buie, 2016); Positive Computing (Calvo and Peters, 2014; Sander, 2011); Positive Design (Desmet and Pohlmeyer, 2013); Persuasive Technology (Fogg, 1999); Computer-mediated Self-transcendence (Gaggioli et al., 2016); Technowellness (Kennedy, 2014); Transcendence Technology (Mossbridge, 2016); User-centered Design (Norman and Draper, 1986); Positive Technology (Riva et al., 2012); Calm Technology (Weiser and Brown, 1996); Affective Computing (Picard, 2010); Ergonomics (Edholm and Murrel, 1973; Jastrzebouski, 2000); Hedonomics (Helander, 2002); Value-Sensitive Design (Friedman and Kahn Jr, 1992); and Emotional Design (Norman, 2004). However, these frameworks did not focus on immersive, interactive technologies (XR) in particular. So, we offered seven design considerations specific to XR in designing for positive states such as self-transcendence based on the analysis we conducted on the design features (input and output modalities) in each of the 33 immersive systems we reviewed.

1. Consider the Outcome and Human Experience First, Then Work Backwards
2. Consider Using Sensory Changes to Support Relaxation, Contentment, and Harmony/Balance
3. Consider Using Movement to Support Calmness, Clarity, and Focus
4. Consider Using Biofeedback for Mediating Changes to the Virtual Environment
5. Consider Mapping Physical and Virtual Movement Together
6. Consider Natural Elements, Minimalist Design, and Child-Like Play for Design Elements and Interaction Strategies
7. Consider the Type of Technology Last, Based on Your Desired Goals and User Experience

We took an existing phenomenological experience, lucid dreaming, linked to both self-transcendence and immersive experiences in order to address RQ2.3 and 2.4. In Chapter 3, we introduced the concept of using lucid dreaming as a lens into understanding and designing for self-transcendence in immersive technology such as VR. There are several parallels between lucid dreaming and virtual reality: the sense of presence in a non-ordinary reality, i.e., feeling like you are there in the virtual environment or dream; your awareness

that the experience is a non-ordinary reality, i.e., you realize you are in a dream or in a virtual environment; and the experience has real-world impacts, i.e., your real-world psychology and behaviour are impacted by what you experience in a virtual environment or dream. Likewise, there are parallels between lucid dreaming and self-transcendence: the experience of an altered state of consciousness; and emotional responses such as joy, awe, wonder, love, forgiveness, and freedom. To dig deeper into how lucid dreaming might inform the design of immersive experiences to support self-transcendence, we conducted phenomenological interviews with nine lucid dreamers (Chapter 4. Their experiences supported our initial presumption that lucid dreaming and virtual reality are similar, while also highlighting some key considerations for design. Some of these insights were already written about in other papers, such as the importance of a multi-sensory experience, vivid and naturalistic imagery, open exploration, and perceived agency. Other insights were more nuanced, including the use of ceremony, minimalism, and degree of interactivity. After gaining an understanding of how lucid dreaming could inform the design of immersive experiences that support self-transcendence, we decided to put this knowledge into practice by designing and evaluating two different immersive experiences: the first to explore mindset and setting for supporting self-transcendence (Chapter 5); the second to explore a lucid dreaming inspired experience (Chapter 6.1 and 7). We were interested in further exploring the design considerations we put forth in Chapters 2 and 4 as well as more deeply examining the parallels between altered states of consciousness like lucid dreaming and virtual reality.

In Chapter 5, we designed a multi-sensory setting surrounding an existing VR experience called the Awe-Inspiring Wellness Environment (Quesnel et al., 2018). We hypothesized that the setting surrounding the immersive experience was important in supporting the feeling of self-transcendence, and our mixed-methods analysis indicated that this was the case. For an experience as deeply personal and emotional as self-transcendence, it's not enough to simply put someone in a VR headset and hope for the best. Rather, we need to think through the experience from the moment of initiation to finally walking away. The phrase "set and setting" is taken from psychedelic research where the mindset of the participant and the setting of the drug trip are crucial in the outcome of the experience itself. Likewise, those designing immersive experiences for self-transcendence should also consider the set and setting. We specifically recommended three main considerations: foreshadow the in-VR experience; establish agency and control; and invite participants to make and experience art as a way to accommodate their self-transcendent experience. This answers RQ2.5 and 2.6.

In Chapter 6, we introduced the design of an immersive environment and neurofeedback system to support lucid dreaming practices. We wanted to explore how the design considerations we put forth previously played out in an actual immersive experience. We took those design considerations and applied them to the design of *Lucid Loop*, an immersive experience designed to support lucid dreaming practices through neurofeedback of brain

waves associated with attention in the form of immersive visuals and audio. To better understand how these design features could support lucid dreaming, a kind of self-transcendent experience, and to answer RQ2.2 and 2.3, we had nine lucid dreamers (different from the phenomenological study above) experience *Lucid Loop* and talk about their experience in a cued-recall debrief interview. Our thematic analysis uncovered several similarities and difference between lucid dreaming and our immersive experience. The similarities were focused attention, fluidity, emotional reaction, techniques to maintain lucidity, and questioning reality. The difference were in the kinds of reality checks, people interactions, multi-sensory experience, and controlability. There were also several mixed comparisons, including lucid affirmations, dream visualizations, nature elements, scene change, and agency. Six design features stood out as being integral in supporting lucid dreaming practices, and perhaps eventually lucid dreaming self-transcendent experiences: alluding to experiences of dreaming, using reality checks, clear points of focus, inclusion of people in the virtual scene, the use of gamma brain wave feedback for focused attention, and the use of HMDs to create an immersive environment.

8.2 Key Insights and Future Directions

I describe key insights that emerged from the various stages of working on this thesis. I offer some suggestions for future work that can further the work on immersive experience design of self-transcendence.

8.2.1 Multimethod Approach to a Multidimensional Phenomena

At the beginning of this thesis, I presented a review paper on the various methods for measuring self-transcendence and offered suggestions given the conceptual model. Yet, what remains to be seen is putting these methods into practice, especially in the field of HCI. When evaluating a technological system that aims to support self-transcendence, researchers and designers should take a mixed-methods approach in order to capture the multi-faceted nature of self-transcendence. Questionnaires and surveys remain one of the most popular methods for measuring self-transcendence, perhaps because of their ease of use and cost effectiveness. However, I would urge those evaluating self-transcendence also consider supplementing these questionnaire data with rich qualitative accounts that may be in the form of interviews, observations, or diaries. Physiological data can also provide an objective measure of self-transcendence, but with the caveat that it too needs some sort of ground truth measure, like qualitative accounts, in order to make sense of the physiological outputs.

8.2.1.1 Future Work

I presented two case studies that explored the design and evaluation of an immersive environment involving self-transcendence. In Chapter 5, we used a combination of semi-structured

interviews, behavioural measures, and questionnaires. In Chapter 7, we used a combination of cued-recall debrief interviews and questionnaires. In both cases, we employed a mixed-methods approach like we suggested in previous chapters. However, the depth of understanding could have been greater if we had also used physiological measures. For example, in Chapter 7, we could have recorded neurophysiological data from the EEG much like several studies that have used EEG. However, the efficacy of using a consumer EEG device to measure something as complex as self-transcendence still needs more evidence and research. In Chapter 5, we might have used diary entries to see how the immersive experience supported self-transcendence (or not) over time. For both case studies, it might have also been interesting to conduct a micro-phenomenological interview in order to better understand the structure of a self-transcendent experience. In future studies of immersive experiences that support self-transcendence, we plan to use a wider variety of measures in order to both understand which methods make sense in the context of VR but also capture self-transcendence from multiple perspectives for a better understanding of this still poorly understood phenomena.

8.2.2 Improving Lucid Loop for Deeper Explorations into the Design of Immersive Experiences that Support Self-transcendence

In Chapters 6 and 7, I presented the design and study of a neurofeedback-based immersive environment that uses 360 video and audio in an HMD for lucid dreaming training. The initial intent of *Lucid Loop* was to help people have more frequent and longer lucid dreams by providing a training ground that drew from the most promising methods of lucid dream induction. Our first step toward this goal was in having proficient lucid dreamers try our initial prototype and discuss their experience in how it related to their own lucid dreams and lucid dream practices. We found that many of our initial design ideas supported lucid dreamer's experiences and practices, and at the same time we found several limitations in our system that warrant more attention in future iterations. While there is much more work to be done, our initial exploration into using immersive technology and neurofeedback for the purposes of lucid dreaming, and perhaps other altered states of consciousness, are promising. One of the limitations is that we still do not know whether neurofeedback or immersive VR are necessary or sufficient for training lucid dreaming. Neurofeedback training could help give people access to unconscious processes, like attention that is important for lucid dreaming, in order to better understand and control them. However, it is unclear what the manner of feedback needs to look like for the neurofeedback training to be effective, e.g., immersive VR, large screen, mobile device, and audio. Immersive VR acts as a training ground that simulates some aspects of dreaming and lucidity from a first-person perspective; the presence one feels in VR might better help with lucid dreaming skills development through state and context dependent memory and learning. However, it is unclear whether this is enough to support lucid dreaming on its own or if the combination of immersive

VR with neurofeedback is needed too. Essentially, we should be careful to not conflate neurofeedback with immersive VR and their potential effects on lucid dreaming.

8.2.2.1 Future Work

We first focused on exploring the potential of immersive and neurofeedback technology for supporting lucid dreaming training. In future iterations, we would like to explore both the impact of *Lucid Loop* on dreaming and, if effective, determine the most efficacious design features and interaction mechanisms that elicit more frequent and prolonged lucid dreams. There are many ways to support self-transcendence, such as profound nature encounters, drug-induced trips, and spiritual or religious experiences. However, the experience of sleep–and by extension lucid dreaming–is something we all have access to. If we can give more people direct access to their dreaming states, then we unlock a world of infinite possibilities including self-transcendent experiences, which we have previously shown to have many benefits and positive impacts on our well-being. We are interested in giving people access to self-transcendence in as many ways possible, including directly in and through VR, because self-transcendence is the key to living your purpose and helping to cultivate the good for the whole of humanity.

8.2.3 Immersive Experiences as a Lens into Altered States of Consciousness

Little is known about self-transcendence for a variety of reasons, including its ethereal nature that makes it challenging to study it in the wild. In Chapter 3, we first introduced the idea of using immersive experiences as a tool for both eliciting and studying self-transcendence. We then narrowed in on one particular experience of self-transcendence, lucid dreaming, to explore the potential parallels with immersive technology since then we would have a more readily accessible and controllable environment in which to study lucid dreaming and other altered states of consciousness relating to self-transcendence. In Chapters 4 and 7, we found there to be several ways in which lucid dreaming and immersive technology are similar, which suggests we might be able to use immersive technology as a way to elicit and study altered states of consciousness in a way that is more controllable and predictable. That is not to say that they are exactly the same conscious experience, but it is curious how an immersive experience can shape our perceptions, behaviours, and beliefs in a way other altered states of consciousness also can.

8.2.3.1 Future Work

The properties of immersive technology, such as virtual and augmented realities, to alter our conscious experience of the world has implications for how we understand and perceive reality. Might these same properties allow us to better understand other states of consciousness? We are interested in exploring the similarities and differences between immersive

technology and altered states of consciousness in order to determine the efficacy of immersive technology for studying altered states of consciousness in order to better understand our experiences of reality. Beyond the psychological applications of immersive technology, we are also interesting in advancing the design space for self-transcendent experiences like altered states of consciousness by applying our insights as design guidelines, i.e, expanding upon Chapters 2, 5, and 7. Psychologists and immersive experience designers alike can benefit from this knowledge in order to provide a more compelling and effective immersive experience for supporting self-transcendence.

8.2.4 Ethical Considerations

This thesis focuses on self-transcendence, which can be a powerful and potentially transformative experience. Much like other containers for self-transcendence, such as psychedelics, people could potentially have strong emotional experiences (positive and negative). As such, we feel it is important to note that when researchers develop and/or study technologies that support a self-transcendent experience they would need to consider how to handle potentially unintended or adverse effects on participants. We recommend working with experts, e.g., psychologist or counsellor, who can help participants work through negative emotions. Moreover, always report situational ethics to the Office of Research Ethics so that future researchers and designers can learn how to both understand and mitigate potential risks.

8.3 Conclusion

Some life experiences can generate profound and long-lasting shifts in core beliefs and attitudes. These experiences can change what individuals know and value, their perspective on the world and life, evolving them as a grown person. For these characteristics, self-transcendence is gaining increasing attention in HCI, Psychology, Neuroscience, and Philosophy. One potentially interesting question related to self-transcendence concerns how it can be invited by means of interactive technologies, such as virtual reality. This question lies at the center of a new research program, self-transcendence experience design, which has two aims: (1) to investigate phenomenological and neurocognitive aspects of self-transcendence, as well as its implications for individual growth and psychological well-being; and (2) to translate such knowledge into design guidelines for developing experiences that aim to support meaning in life and personal growth. We have begun to address these aims by describing the conceptual theories of self-transcendence and clarifying the methods in which to measure self-transcendence given different conceptual models. We have also focused on designing for self-transcendence by engaging in the design of two different immersive experiences that support awe and lucid dreaming. The potential wisdom and benefits that come from self-transcendence are great, yet the topic is surrounded by pseudo-science and misinformation. We must go forth with a sense of rigour and multidisciplinary perspective

if we are to further advance the field and emerging challenges that come with an undefined and vast topic. I, for one, welcome the "wonderful possibilities and inscrutable depths in mankind"[1] that are revealed through studying and experiencing self-transcendence.

[1]Taken from a quote by Abraham Maslow. Lowry, A. H. Maslow: An intellectual portrait, pp. 14-15.

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Appendix A

Chapter 1: Supplementary Material

Description:

This is from Chapter 1, a review on methods for measuring self-transcendence. Here, we list each measure, its goal, the basic methods, advantages, disadvantages, suitability, reliability and validity, and which research papers use the measure.

File name:

ST_Methods_Comparison_Table.pdf

Appendix B

Chapter 2: Supplementary Material

Description:

This is from Chapter 2, a scoping review on immersive interactive technologies for positive change. Table 1 shows the different types of XR and technologies/platforms used in each experience we reviewed. Table 2 lists and summarizes each experience we reviewed in terms of well-being and positive functioning, type of XR, technology used, platform, target user, number of users in study, input/output modalities, design elements and interaction strategies used, outcome, and how the design elements and interaction strategies contributed to support positive change and/or elicit positive states.

File name:

XR_Review_Tables.pdf

Appendix C

Chapter 7: Supplementary Material

Description:

This is from Chapter 7, an exploratory study on an immersive environment and neurofeedback system with modified deep dream 360 video to support lucid dreaming practices. First describes the questionnaires used in the study, including the demographic information, dream and lucid dream questionnaire, and the mindful attention awareness scale. Second details the qualitative analysis code book containing the themes, sub-themes, their definitions, and the number of references made for each in the interviews.

File name:

LLquestionnaire.pdf

LLcodebook.pdf