On presence and emotions

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Award date:
2021

Eindhoven, March 2021

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in partial fulfilment of the requirements for the degree of

Master of Science

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Abstract

Presence is a phenomenon vital and inherent to the workings of virtual reality. Considerable evidence has emerged that presence is related to the phenomenon of emotion, however research into specific causal interactions lacks coherence. The current thesis aims to bridge this gap, to be the first study to provide a thorough overview of emotion-presence dynamics in literature, and provide a theoretically-driven interpretation of results. First, a literature review is conducted. For concepts of presence and emotion, their structure, formation, and possible interactions are considered from a theoretical perspective. Second, a systematic literature review is conducted. Numerous databases were explored (i.e., ACM Digital Library, PsychArticles, SCOPUS, Web of Science), and after a practical and qualitative screening, 37 articles were included in the review. Of interest were investigations into the *correlation* between presence and emotion, the causal *effect of emotion on presence* and *of presence on emotion*, and possible *reciprocal* dependencies. In order to better interpret the results and understand the dynamics, the role of other possibly relevant factors was investigated (e.g., presence measure adopted, emotion type measured). Results were interpreted, by evaluating the percentage of studies which found significant results, for each investigation. General results showed a convincing support for all directions of the emotion-presence relationship, for all manner of emotions. There are indications, however, that the reciprocal dependency may be more complex (temporally or otherwise). Lastly, the theoretical implications of the results are discussed in detail.

On Presence and Emotions

Virtual Reality (VR) can be described as a computer-generated, interactive, multi-sensory, 3D environment (Schultheis et al., 2002). It is a technical phenomenon, which has come to positively contribute to numerous fields in everyday life, such as gaming (Stanney, 2002), research (Diemer et al., 2015; Kim et al., 2014), medicine (Bush, 2008; Gold et al., 2006; Keefe et al., 2012; M Krijn et al., 2004; Rizzo et al., 2005), training (Ai-Lim Lee et al., 2010; Bailenson et al., 2008; Mikropoulos & Strouboulis, 2004; Vora et al., 2002), and even long-term behavioral change (Ahn et al., 2013; Fox et al., 2009; Gillath et al., 2008; Girard et al., 2009; IJsselsteijn et al., 2006; Rosenberg et al., 2013).

Inherent to the successful application of VR, is a psychological phenomenon called *presence* (IJsselsteijn & Riva, 2003): often defined as the illusion of physically "being there", in the virtual environment (VE; Steuer, 1992). It has always been considered a vital part of VR (Baños et al., 2008), has even been referred to as the "key of virtual reality" (Baños et al., 2004, p. 1), and is believed to be one of the main factors contributing to its effectiveness (Schuemie et al., 2001). Specifically, presence is related to greater enjoyment of the VR experience (IJsselsteijn et al., 2006; Larsson et al., 2001; Shafer et al., 2011; Sylaiou et al., 2010; Tussyadiah et al., 2018), and to a positive effect on attitude, belief, intention and performance inside the VE (Lombard & Ditton, 1997; Schuemie et al., 2001; Suh & Lee, 2005; Tussyadiah et al., 2018; Vora et al., 2002). Furthermore, presence has been identified as the main mechanism responsible for the effectiveness of VR exposure therapy (Price et al., 2011; Wiederhold & Wiederhold, 2006).

Since the rise of presence research, the aim has been to identify factors (related to the user, the media, or otherwise) that influence the formation of presence in VR. The goal is to manipulate such factors to enable and stimulate presence. In the early years, this research focused specifically on cognitive-, environmental- (Huang & Alessi, 1999) and technological

variables (Hendrix & Barfield, 1996; IJsselsteijn et al., 2001; Welch et al., 1996). For example, user characteristics such as perceptual-, motor- and cognitive abilities were found to influence the formation of presence (Witmer & Singer, 1998). Furthermore, it has been found that more immersive technologies (such as an HMD) are better able to evoke presence than less immersive technologies (such as a 2D monitor) (Baños et al., 2004; Roettl & Terlutter, 2018; Shu et al., 2019) . In more recent years, however, research has focused on a previously disregarded factor that appears to correlate with presence, namely *emotion* (Alsina-Jurnet et al., 2011; Baños et al., 2004; Bouchard et al., 2008; Price et al., 2011; Price & Anderson, 2007; Riva et al., 2007; Robillard et al., 2003).

Emotions have been defined as short-term states of feeling (Freeman et al., 2005), and they are known to play a vital role in guiding human experience and interpreting events (Huang & Alessi, 1999; Riva et al., 2007). However, due to initial disregard of emotional aspects in early years of presence research (Huang & Alessi, 1999), it remains unknown how precisely emotion impacts, or is impacted by, presence. At first glance, literature shows no consensus regarding whether affective content increases presence (Baños et al., 2004; Bouchard et al., 2008), presence facilitates emotion (Price & Anderson, 2007), the relation is circular (Heeter, 1992; Riva et al., 2007), or perhaps nonexistent (Freeman et al., 2005). This is concerning especially when considering that VR is known to be an “affective medium” (Riva et al., 2007), meaning it is highly capable of inducing emotional responses (Baños et al., 2006; Botella et al., 2007; Han et al., 2009; Riva et al., 2007).

Understanding the relationship between presence and emotion may prove to be beneficial in three ways. First, in terms of applicational value, it may assist developers in designing more effective VEs. For instance, if researchers aim to evoke presence in their VE, and

results show that emotions increase presence, then it may be valuable to focus on generating VEs with emotional content.

Second, from a scientific point of view, understanding the role of emotion in the presence experience, will contribute to the understanding of the complex phenomenon of presence. Specifically, it may give some insight into presence aspects such as its structure, consequences, determinants and measurements (Dillon et al., 2002); knowledge which to this day remains inconclusive (Sadowski & Stanney, 2002; Schuemie et al., 2001; Wiederhold, 2003).

Third, and perhaps most important to consider, is that improved understanding of the dynamics between presence and emotion, may remove a potential confound in presence research. There appears to be some empirical evidence that emotion moderates important processes related to presence (Baños et al., 2004; Gorini et al., 2011; Lombard & Ditton, 1997; Ravaja, 2004). More specifically, in numerous studies it has become apparent that measuring the relationship between presence and immersion may lead to different results, depending on whether or not emotions are present (Gorini et al., 2011). How emotions and presence interact exactly remains unknown, and not understanding and particularly accounting for the way in which emotions interact with presence, may introduce a confound. This is an especially relevant consideration, given the fact that emotion is inherent to the VR experience (Riva et al., 2007). To the knowledge of the current author, this is the first study to conduct a systematic review of research regarding the relationship between emotions and presence.

It is important to note, however, that interpreting presence research is not necessarily straight-forward. While presence is often defined as the illusion of physically being in the VE, it is in fact a phenomenon that has been defined and interpreted in a variety of ways (Lee, 2004). Furthermore, presence is also considered to be complex and multifaceted (Baños et al., 2004; IJsselsteijn et al., 2000). Numerous theories exist regarding the nature of presence, the facets

that presence is thought to consist of, or the processes involved in its formation, but limited consensus exists among those theories (Sadowski & Stanney, 2002; Schuemie et al., 2001; Wiederhold, 2003). Therefore, it is important to note that the ambiguity in study results acquired so far, regarding the relationship between presence and emotions, may stem from different sources. It may not only be a result of the variety of different study designs used, but may also be due to differences in the theoretical foundations adopted by the researchers (e.g., definition of presence). Understanding the relationship between presence and emotions, hence, not only requires a critical analysis of study designs and results, but also of the underlying theoretical foundations adopted by the researchers of the various studies conducted, which will be an integral part of the current thesis.

Based on the information above, the general research question will be *What is the general consensus in literature regarding the relationship between presence and emotions?* This research question will be further divided into four sub-questions. 1*. What are the current theories regarding presence, emotions, and the relationship between presence and emotions? 2. What is the existing empirical evidence regarding the relationship between presence and emotions? 3. How do the different empirical findings compare to each other, in light of their theoretical foundations? 4. How can a future experiment be designed to shed more light on the relationship between presence and emotions?*

The current thesis will attempt to answer the questions above in the following way. It will start with a literature review, in which a detailed overview and evaluation of the currently available knowledge regarding key topics such as presence and emotions is provided, along with theories and reasoning regarding their dynamics. It will then proceed with a systematic literature review of relevant studies, and critically evaluate and compare their theoretical

foundations, experimental designs, results and interpretations. Lastly, based on the findings, a proposal will be made for a future study design.

Literature review

Before being able to compare different studies investigating the relationship between emotions and presence, it is important to provide current-day knowledge on the key topics involved in this evaluation. These topics are threefold. First, it is important to dive deeper in the concept of *presence*, such as its definitions, structure, and ways of measurement. Second, it is important to discuss *emotion* in a similar manner. Third, it is important to discuss and theorize the way in which emotions and presence may interact, based on the theories available. The current knowledge available on all three topics will be discussed below, before moving on to the systematic review across relevant studies.

Presence

Presence is often considered psychological phenomenon (Biocca, 2006), also sometimes referred to as a *state of consciousness* (Slater & Wilbur, 1997, p. 605). It is most commonly used to describe the feeling of *being* in an environment (Steuer, 1992), however a range of different definitions and conceptualizations also exist (Lee, 2004). Despite the fact that presence is regarded as one of the most important components or effects of the VR experience (Baños et al., 2004; Baños et al., 2008; Schuemie et al., 2001), it remains unknown what the exact nature of it is, how it is created, and how it can be measured (Sadowski & Stanney, 2002; Schuemie et al., 2001; Wiederhold, 2003). The rest of this chapter will present an overview the current-day knowledge regarding presence.

Defining presence

Scientists from a multitude of different fields have attempted to define the phenomenon of presence. This has led to presence being described through numerous

theoretical lenses (Diemer et al., 2015), leading to the emergence of numerous different definitions and subtypes (Lee, 2004). Some of these different definitions and subtypes are found to be overlapping in nature in noninterchangeable way, which complicates the process of comparison across studies (Lee, 2004). Different researchers studying presence may actually be studying different phenomena, based on their theoretical assumptions. Concretely, the use of poorly defined terms has led to a lack of coherence in the available literature (Lee, 2004).

In order to conduct a systematic analysis of studies on presence, it is important to be aware of the different theoretical assumptions adopted under the term *presence*. Furthermore, when doing investigations into presence research, a second difficulty emerges. Specifically, in terms of terminology, multiple terms are often used to refer to the same phenomenon (e.g., media presence and telepresence). It is important to be aware which are, or are not, comparable. The rest of this chapter will focus on explicating the different theories and terminologies.

Theoretical foundation. In general, the different theoretical perspectives of presence can be organized into a number of categories. When investigating current day literature, there are two categories especially current and relevant, namely those which conceptualize presence according to the notion of *media presence*, and those which conceptualize presence according to the notion of *inner presence* (Villani & Riva, 2008).

Media presence. Researches in the media presence category tend to describe presence as a *perceptual illusion of non-mediation* or as a *place illusion*.

Lombard and Ditton were one of the first to define presence as *the perceptual illusion of non-mediation* (Lombard & Ditton, 1997). They state that presence occurs when users forget about both the real (external) environment and the media technology, and no longer consciously perceive and react to it, but to the mediated environment instead (Lombard &

Ditton, 1997). The term p*lace illusion* was first coined by Steuer (Steuer, 1992) as "the extent to which one feels present in the mediated environment, rather than in the immediate physical environment" (p. 76). This term coincides with the previously mentioned sense of *being there.* Schuemie and colleagues (Schuemie et al., 2001) found the notion of *place illusion* to be the most common reference to presence in literature, and numerous researchers have adopted similar definitions of presence (Baños et al., 2008; Barfield & Hendrix, 1995; Barfield & Weghorst, 1993; Bystrom et al., 1999; Freeman et al., 1999; Held & Durlach, 1992; Schubert et al., 2001; Sheridan, 1992; Slater et al., 1994; Wirth et al., 2007; Witmer & Singer, 1998).

Regarding how *illusion of non-mediation* and *place illusion* conceptualizations relate to each other, there is some discussion. Most authors believe that the notion of *place illusion* (i.e., the sense of being in a mediated environment) is naturally implied inside the concept of *illusion of non-mediation* (Lombard & Ditton, 1997; Slater et al., 1994). Specifically, they believe that if individuals forget about the mediating technology (i.e., an illusion of non-mediation is achieved), then the mediated environment is automatically accepted as a real place that one is physically situated in (i.e., place illusion is achieved).

Other authors, however, believe the two are distinct, and that *illusion of non-mediation* is not necessary to experience *spatial presence* (Wirth et al., 2007). Specifically, Wirth and colleagues believe the *illusion of non-mediation* is a global sensation experienced during exposure to the mediated environment, which can be experienced with or without feeling physically present. In other words, one does not need to deactivate cognitive information regarding their actual physical location, in order to feel presence. They do note, however, that the experience of *spatial presence* may fuel the experience of the *non-mediation illusion*.

Inner presence. A group of opposing theorists exist that critique this view of media presence. They refer to media presence as the "technical definition" of presence (Villani & Riva,

2008), and more specifically, they state that media presence theorists regard presence as a result of technology, while it should be regarded as a common human experience independent of technology (Waterworth et al., 2010). Inner presence theorists believe presence is core to the experience of consciousness (Waterworth & Waterworth, 2010). It is thought to be a biological phenomenon, which can be described as the feeling of physically being present in an external world, in the here and now. The function of presence is to ensure that organisms pay attention to stimuli in their immediate environment that may be essential to their survival (Waterworth & Waterworth, 2010).

Further explaining their view of presence, Waterworth and colleagues (2010) believe that presence should be seen in relation to *the self* and *the other.* It mentions two opposite poles which are considered two ends of a continuum, namely the *absence* and the *presence* poles. Total *absence* is a complete absorption into one's internal world (*the self*), where thinking and imagination takes place. Total *presence* is a complete absorption into the external outside world (*the other*). When one experiences presence, one places themselves on a point along this continuum (Waterworth et al., 2010). Typically, at any point in time, one would experience both *presence* and *absence* (Waterworth & Waterworth, 2010), however the degree to which each end is experienced differs.

Building on this, Waterworth and Waterworth believe *absence,* being in one's internal world of thinking and imagination, is able to evoke similar emotional experiences and intellectual engagement as the external world would, however not the feeling of presence (Waterworth, 2005). Specifically, Waterworth and colleagues believe that the feeling of presence is the main mechanism organisms have to distinguish between the internal world (the absent self) and the external world (the present other).

In light of interactions with media such as VR, inner presence theorists make a distinction between presence experienced in the real (external) environment, and presence experienced in the VE. They state that creators of VEs typically attempt to generate mediated environments which engage users in a similar way real environments do, and when they are successful, they are able to generate a sense of presence similar to real-world presence, or rather an *illusion* of presence. When presence is experienced inside a VE, inner presence theorists define it as "the perceptual illusion of being in an external environment" (Waterworth, 2005, p. 1).

Media presence versus inner presence. As was previously highlighted, the critique that media presence theorists receive from inner presence theorists, is that the media presence group tend to approach presence as an experience arising from interaction with a certain mediated technology (Villani & Riva, 2008). Authors from the inner presence group believe the fault with this, is what the media presence theories do *not* explain. More specifically, Riva and colleagues (2011) state that any theories regarding presence should be more concerned with *why* presence arises, what kind of phenomenon presence is in our daily lives, and not only in response to a media technology. In other words, this view reflects the difference that the inner presence group focuses on presence from a psychological or ecological perspective (Villani & Riva, 2008), and, although the media presence conceptualization does not disregard psychological or ecological components of presence, most media presence theories (but not necessarily all) tend to focus on cognitive and media factors instead (Villani & Riva, 2008).

While presence theories of the media presence group and inner presence group differ, it is important to mention that they do, at least to some extent, describe the same core feeling. This core feeling is that a (mediated) environment feels as if it were real, and as if one is actually situated inside it. Whether this is because an individual feels physically transported to the virtual

environment (place illusion), whether the individual forgets about the mediating technology (illusion of non-mediation), or whether this individual is simply more present in the external world rather than the internal world (inner presence), in each instance an individual believes the virtual environment to be real, at least to some extent.

Terminology. *Telepresence, virtual presence, mediated presence, physical presence, spatial presence* (and sometimes even *presence*) all refer to the same concept. *Telepresence* was first mentioned by Minsky (1980), explaining the phenomenon of human operators feeling like they are "physically transported to a remote work space via teleoperating systems". *Mediated presence* is a similar term, among others used by Biocca and colleagues (2003) to specifically refer to presence experienced in *mediated environments*. Sheridan (1992) started using *virtual presence* for the same phenomenon, but specifically for VR technologies, in order to differentiate between different types of media technologies. *Physical presence* has been referred to "the sense of being physically located somewhere" (IJsselsteijn et al., 2000, p. 3). *Spatial presence* is often referred to as a "the feeling of being in a remote and/or mediated environment" (Schubert et al., 2001). Lastly, *Presence*, when defining it according to theoretical notion of *place illusion*, can be defined as "the sense of being there" (Steuer, 1992).

All terms are congruent in the manner that they have, at their core, a sense of feeling physically present at a (remote or computer simulated) location, hence it can be argued that they all refer to the same phenomenon, namely presence in the sense of *place illusion*. In the following investigations into presence, these terms will henceforth also be considered comparable and interchangeable.

Presence formation

Structural models of presence have been developed, which concern the formation of presence, and aim to more specifically explain how presence comes to be. Each theory has their

own reasoning regarding the aspects the presence phenomenon may consist of, and which factors play a role in its formation. The most complete and substantial theories regarding the formation of presence will be elaborated upon below, both from the perspective of researchers from the *media presence* and *inner presence* group.

This section on theories of presence formation was included not only to provide a better understanding of the construct of presence, but also to investigate the theoretical basis on which emotions and presence may interact. More specifically, in order to better understand the role that emotion may have in presence generation from a theoretical point of view, it is important to discuss existing theories of presence formation, and the way in which emotion may or not may a role in the process. At a later phase of the current thesis, a similar process will be repeated regarding the role that presence may have in theories of emotion generation (see section *emotion formation*). That way, both possible directions of the emotion-presence dynamics are considered from a theoretical point of view, which allows the interpretation of the systematic literature review results to be easier and more meaningful.

Inner presence group. Given the lack of studies conceptualizing presence according to the notion of *inner presence*, the number of considerable theories explaining the formation of *inner presence* is but singular.

Three-layer evolutionary model of presence. According to the three-layer evolutionary model of presence, the main goal of presence is to differentiate between the internal and external world (Riva et al., 2004). Damasio has previously established three levels of self, namely *proto self*, *core self*, and *extended self*, each relevant in its own way for the separation of the internal and external world (Damasio, 1999). The three-layer evolutionary model of presence takes inspiration from Damasio's three levels of self, and instead refers to three levels of

presence, namely *proto presence*, *core presence*, and *extended presence*, all developed by Riva and colleagues (2004).

Proto presence is related to separating the *self* with the *non-self*. In other words, it is a type of embodied presence. It concerns non-consciously assessing one's own physical state, and separating it from the external world. Vital to this phase is movement, which allows internal sensorimotor representations and perception-action coupling on the one hand, to be differentiated from sensory information from the external world on the other hand.

Core presence is related to differentiating between the *self* and the *present external world*. It is a conscious process, continuously re-created, and it involves perceiving the world surrounding the body in the current timeframe, and integrating sensory information into single perceptions. In order to effectively perceive the external environment, knowledge from past experiences and evolutionary history is used. This phase is thought to largely be guided by *core affect*, or feeling states, which facilitates accessibility and attention, and drives what exactly is processed by core presence.

Lastly, *extended presence* connects what is currently happening to stored knowledge and memories from past experiences, to beliefs, skills, hopes, and learned ideas. It adds value to the present. It is also what infers about possible future experiences. It allows for the formulation of internal goals, and the tracking of their achievements.

Three-layer evolutionary model of presence, and emotion. According to Riva and colleagues (2004), emotion is able to directly affect two facets of presence. First, as was previously mentioned, *core presence* is strongly influenced by core affect. When changes in core affect are experienced, it is vital for the core self to focus on the current external sensorial experience, and find the source responsible for the changes in affect. In a way, changes in affect guide attention and increase the level of core presence. A high level in core presence, in turn,

allows individuals to behave as if events are real, and is the mechanism responsible "fooling" individuals into experiencing presence in e.g., virtual reality.

Second, emotional experience is linked with *extended presence*. As was previously mentioned, extended presence is used to provide meaning to current situations. Core affect in itself is able to exist without being attributed, interpreted or labeled, depending on whether or not *extended presence* attends to it. And this is not necessarily always the case, as extended presence can be active in both one's internal and external world. If it regards the internal world and not the external world, then no meaning to external factors such as core affect is attributed.

For the sake of the current investigation, and following the three-layer evolutionary model of presence, it can be expected that emotion can contribute to the formation of presence, and a causal effect of emotion on presence is to be expected. However, depending on whether one is attending to the internal or external world, this effect of emotion on presence may at times be diminished.

Media presence group. Below is an overview of models and theories used to explain the formation of presence, provided by authors of the media presence group. In this phase, only the more established theories to presence are discussed.

Embodiment and presence. The aim of the theoretical framework by Haans and IJsselsteijn (2012) is to take technological and psychological factors, that research showed were important in generating telepresence, and combine them into a comprehensive theoretical framework. They argue that *embodiment* is vital in the generation of telepresence.

Embodiment is commonly defined as *being an active participant in the world* (Haans & IJsselsteijn, 2012; Zahorik & Jenison, 1998). In line with findings by Metzinger (2006), the authors believe there to be three orders of embodiment. The first order entails only having a

body morphology, the second order entails having morphology and a body schema, and the third order entails having morphology, a body schema and a body image.

To have morphology, simply means to have a body. In case of the human body, this entails having a specific number and specific types of limbs. It is the morphological characteristics of an organism that enable or constrain its behavior and action possibilities, just like wings tend to allow for flight, and eyes allow for sight.

In body schemas, the individual parts of one's body are combined into a coherent functional unity. Body schemas are used for continuous and automatic regulation of movement and posture, essentially guiding behavior. Furthermore, they keep track of the body's position in time and space. Having a body schema allows for fluent and simple interactions with the environment, even if such an interaction requires complicated body movements. Regarding the formation of this body schema, there is considerable evidence that the body schema is constructed and updated through interaction with the environment, and sensorimotor integration.

Body image can be explained as an individual's perception and long-lasting awareness of their body, and the conceptual knowledge, emotions and memories individuals may have of their body. It can also be considered one's *consciousness* of their own body. It is thought to evolve through a process which combines and extracts correlations between information from the multisensory modalities, connects that multisensory information with memory content, and refines perceptual discriminations and categorizations. For body image to take place, the central nervous system needs to categorize a body as part of one's self, rather than part of the external world.

Tools can be used to extend the action possibilities of organisms: having a hammer allows individuals to use more force, and glasses improve their sight. Thus, when using tools, a

temporary, functional extension of *morphology* takes place. However, regularly using tools and becoming fluent and proficient with them, requires having a dynamic *body schema*. In that case, the body schema is updated in such a way that the tool is included inside the schema. Next to the functional extension of the body, it is also possible that a phenomenological extension of the self takes place. This entails that individuals acquire a sense of ownership over e.g., virtual body parts. This requires capability of experiencing *body image.*

This adoption of tools into the body schema is also what may happen when using immersive media technology, such as a head-mounted display. When the mediation technology is adopted into one's body schema, then it becomes possible for individuals to interact with the mediated environment as if the mediated technology is not there, without conscious effort. This could once again be compared to having eyes: an individual is able to see through them, without being aware of them (See: Biocca, 2006). If a mediated technology is successfully adopted into one's body schema, then an illusion of non-mediation, and by extension an illusion of being physically located in the mediated environment arises, a.k.a. (tele)presence. Whether the adoption into the body schema takes place, and if so, how well, can depend on numerous factors. This may be in the form of technological factors, such as delays, image quality, and field of view. However, what has become clear in research, is that active and effective interaction with the environment (and as such sensorimotor integration) allows the body schema to adapt to inter-sensory conflict, and allows for embodiment and thus the generation of (tele)presence.

Embodiment and Presence, and Emotion. In the current theory of presence formation, aspects such as *effective interaction* with an environment and *technological factors* are mentioned to play a role in whether or not a mediated technology is adopted into one's body schema, and presence is formed. No factors are mentioned in the model that may relate to the

variable of emotion, hence using the current framework, it be expected that a relationship between presence and emotion is nonexistent.

Ecological view of presence. The ecological view of presence is based on the ecological theory of perception (Flach & Holden, 1998; Schuemie & Van der Mast, 1999; Zahorik & Jenison, 1998). This view believes that organisms view the different elements of their environment in terms of their possible interactions, or their *affordances* (Schuemie & Van der Mast, 1999). As an example, the floor *affords* walking and scissors *afford* cutting. In other words, perception of the world is linked to the possible actions inside that world (i.e., interactivity). Building on this, the ecological view of presence says that the interactivity of a medium is the most important feature to facilitate presence (Schuemie & Van der Mast, 1999).

More specifically, It identifies three phases to the formation of presence. First, the mediated environment should offer situated affordances (Schuemie et al., 2001; i.e., the possible bodily actions supported by an environment; also Gibson, 1979). Second, a perception-action coupling will occur. This phase represents the user perceiving the mediated environment through those affordances, with perception becoming dependent on possible actions (Schuemie et al., 2001). Third, *tools become ready-to-hand* (Schuemie et al., 2001). As stated by Heidegger (2010), this entails that using a tool will provide users with a stable representation of the tool. Users will no longer be physically aware of the tool, and only of the usefulness of it, and of the task it is performing. In virtual reality, this entails that the technology will become *invisible* to the user, and all the user is aware of, is the VE provided to them (Schuemie et al., 2001). Zahorik and Jenison (1998) conclude that the successful support of actions inside a mediated environment (i.e., successful meaning *similar to the real-world*), leads to the perception of oneself existing inside that environment, which leads to a sense of presence.

In some ways *embodiment framework* by Haans and IJsselsteijn (2012) is quite similar to the current *ecological view* of presence (Zahorik & Jenison, 1998), as both believe that effective interactions with the environment allow for the tool becoming *invisible*, and consequently the generation of presence. However, both approach the generation of presence from different theoretical points of view: Haans and IJsselsteijn (2012) speak of orders of embodiment, while Zahorik and Jenison (1998) speak of affordances.

Ecological view of presence, and emotions. The *embodiment framework* and the *ecological view* show a similar view of presence, namely that the formation of presence is dependent on successful acting within the VE. In a similar vein to the *embodiment framework*, the *ecological view of presence* also does not include any relevant variables that may relate to emotion, hence adopting this framework, no relationship between presence and emotion is to be expected.

Interoceptive predictive coding model. Seth and colleagues (2012) propose a theoretical neurocognitive model of presence. The main aspect of the framework is related to *interoceptive predictive coding*. The model includes a variety of brain regions, however in order to keep information relevant and concise, those will be disregarded for the time being.

Interoception is related to the perception of the physiological state of your body, which reflects subjective feelings and activity of the autonomic nervous system. *Exteroception*, on the other hand, refers to perception of all stimuli outside of the body, such as the environment, the positioning of the body and limbs and sensorimotor information.

Predictive coding then concerns the flow of top-down signals (i.e., prediction and expectation signals), the bottom-up signals (i.e., sensory- and prediction error signals), and the way in which they interact. The notion of *interoceptive predictive coding* hence entails that one's expected interoceptive states (what an individual expects to feel when encountering the

environment) are continuously compared to one's actual interoceptive states (what an individual actually feels). Seth and colleagues suggest that presence is a result of this interoceptive predictive coding. If there is a congruency, or rather a match, between predicted and actual interoceptive signals, then presence is achieved. If considerate prediction errors are detected, presence is not achieved. The authors state that a prediction error can always be expected, but it is the suppression of the mismatched signals that is vital for enabling presence.

In the predictive coding model, this dynamic between interoceptive predictive coding and the formation of presence, is called the *presence* component. There is also another component relevant to the model, related to exteroception rather than interoception, called the *agency* component. The *agency* component concerns sensorimotor signals (exteroception) rather than autonomic signals (interoception). It also functions through mechanisms of predictive coding, in which sensorimotor prediction signals, sensorimotor signals, and sensorimotor prediction error signals continuously interact. The *agency* component is also able to provide input to the *presence* component, and thus aid in the formation of presence.

This view highlights that there should not only be a good match between expected and actual *interoceptive* information, but also between expected and actual *sensorimotor* information. They do note, however, that agency is not considered necessary nor sufficient for presence. In their view, presence can occur on the basis of *interoception* only, and sensorimotor integration is not necessary.

To conclude, the interoceptive predictive coding model by Seth and colleagues highlights the importance of one's *internal environment*, rather than *external environment*. Presence is achieved if there is a match between what an individual feels and expects to feel. Additionally, if there is a match between predicted and actual sensorimotor information, this contributes to the formation of presence, however this is neither necessary, nor sufficient.

Interoceptive predictive coding model, and emotions. According to this model, interoceptive signals, and by direct extension subjective feelings, are the most important factors involved in the generation of presence. As was previously mentioned, presence is thought to be the result of successful predicted interoceptive coding; if an emotion is experienced when emotion is expected, this enhances presence. In other words, if a VE is able to evoke emotions just like a real environment would, this enhances presence. In light of this, one may expect emotion and presence to be correlated, and one may also expect a causal effect of emotion on presence to arise, but only if it is context appropriate.

Spatial-situational model. The model proposed by Wirth and colleagues (Wirth et al., 2007) concerns spatial presence as a two-dimensional construct, the first dimension related to the positioning of oneself in an environment (*self-location*), and the second dimension related to perceived possibilities to act (*situated affordances*). The model provides an explanation for the formation of presence, using the notions of *mental models* and *situated affordances*. It is in line with numerous existing models (Glenberg, 1997; Kim & Biocca, 2006; Schubert et al., 1999), however pays more attention to explaining necessary conditions and contributing processes (Wirth et al., 2007).

Wirth and colleagues propose that there are two vital steps to achieve the experience of Spatial Presence. This first step involves answering the question “what kind of space is this I am seeing?”. It concerns creating a mental representation of the environment, called the “spatial situation model” (SSM). The SSM is created by integrating space-related sensory information, individual memories, and cognitions regarding space (McNamara, 1986), and it is facilitated by attention allocation. This entails that only individuals who pay attention to the mediated environment, are able to experience presence. The SSM is considered a precondition for the experience of presence to occur.

The SSM is updated real-time, and there is always a finished model ready for use (Schnotz, 1988). In multimodal environments, information from the different modalities must agree in order to create a consistent SSM (Held & Durlach, 1992; Witmer & Singer, 1998). Both media factors (e.g., attention-catching content and spatial cues) and user variables (domain-specific interests and spatial visual imagery) will affect the development of SSM.

In the second step, the question to be answered is "am I situated in this space?". In this space, the actual formation of spatial presence takes place, and it originates from the SSM. Vital in this step, are *egocentric reference frames* (ERFs). ERFs are hypotheses regarding the location of the user, and are constructed and maintained through continuous acquisition of information by the sensory modalities (Riecke, 2001). ERFs contain all the objects perceived in the environment, including one's own body. When using VR, multiple ERFs may exist – one of the real environment, and one of the VE. In the case of multiple (conflicting) ERFs, one Primary Ego Refence Frame (PERF) must be selected. The PERF is the frame the individual believes he or she is located in. It is also the frame the individual wishes to align all spatial perceptions and perceived action possibilities with, in the case of sensory incongruencies.

When located in a mediated environment, with the existence of the SSM, perceptual hypotheses are created regarding whether or not the mediated space is the space the individual is actually located in. This hypothesis is called the "medium-as-PERF-hypotheses". Spatial presence is thought to occur when the "medium-as-PERF-hypotheses" are accepted, and perceived location, possible actions and mental capabilities are all centered on the mediated space. Accepting the SSM and the medium-as-PERF hypothesis not only establishes a feeling of being located inside the mediated environment, but it also establishes a feeling of being able to act within the mediated environment. (Hofer et al., 2012). If this is not the case, then users will remain believing they are in the real world (real world as PERF), even though the mediated ERF

may seem very convincing. Basic processes of perception and cognition must be considered in the formation of the model (Darken et al., 1999; Taylor, 1997).

Spatial situational model, and emotions. With regard to the role that emotion might have in this model, it once again comes down to attention, just like three-layer-evolutionary model by Riva and Waterworth regarding the formation of inner presence (Riva & Waterworth, 2003). Attention allocation is vital in the current model; if attention is not allocated, the SSM is not formed and presence does not evolve. Research has shown that emotion is capable of doing just that – directing attention (Dreisbach & Goschke, 2004; Oatley et al., 2006; Olivers & Nieuwenhuis, 2005, 2006). Hence, one would expect that, when adopting the spatial situational model for the formation of media presence, that emotion will facilitate presence formation, and data will show a causal effect of emotion on presence. However, it is important to note that in the current model, emotion is not necessary for presence to exist. If there are other factors already allowing for attention allocation, the link between emotion and presence may not be as pronounced.

Presence measures

Presence can be measured through subjective measures (e.g., self-report measures) (Witmer et al., 2005), and objective measures (e.g., behavioral and psychophysiological measures) (Freeman et al., 2000; Meehan et al., 2002). Due to the different conceptualizations of presence, a range of different measures have emerged for each category of measurement.

Each presence measure tends to make certain (implicit) assumptions about the concept of presence, what it consists of, and how it arises. Thus, in order to fully understand the results obtained in the systematic literature review, it is important to understand the measures adopted by these studies, and how these measures relate to each other. Therefore, the most common presence measurements used in research, will be discussed below.

Self-report measures. By-far the most common type of measurement takes place post-experiment and is through self-report (Slater & Steed, 2000).

Igroup Presence Questionnaire. First coined by Schubert and colleagues (Schubert et al., 2001), the Igroup Presence Questionnaire is a measure of presence. It consists of 13 items, and is answered using a 5-point Likert scale, ranging from *not at all true* to *completely true*. The items are constructed based on two assumption. First, that presence can be conceptualized according to the notion of *place illusion*. Second, that presence consists of 3 components. The first factor is spatial presence, e.g., the sense of being in the VE. Second is involvement, e.g., attention paid to the virtual environment. Third is realness, e.g., how much the VE coincides with the real world.

ITC – Sense of Presence Inventory. The ITC-SOPI is a type of presence measure, developed by Lessiter and colleagues (2001). It consists of 44 items, all which are answered using a 5-point Likert scale, ranging from *strongly disagree* to *strongly agree*. It is constructed to be purely a reflection of an individual's experience of the media, rather than objective media characteristics.

The content of the items is based on the results of an exploratory analysis, which proposes presence consists of four factors. The first factor is physical presence, i.e., the sense of being there, in the VE. Second is engagement, i.e., involvement of the user and intensity of the experience. Third is ecological validity, i.e., believability and naturalness of the content. Fourth is negative effects, i.e., side effects as a result of using the VR technology, such as dizziness and nausea.

***Presence Questionnaire*.** Also called PQ, this questionnaire is produced by Witmer and Singer (Witmer & Singer, 1998), and aimed at measuring presence in VEs. It measures presence by specifically looking at contributing factors such as *control factors* (e.g., degree of control an

individual has), *sensory factors* (e.g., environmental richness and use of sensory modalities), *distraction factors* (e.g., isolation from the real environment, selective attention) and *realism factors* (e.g., consistency with the real world, meaningfulness of experience). The 32-item questionnaire is answered using a 7-point scale format.

In the creation of this questionnaire, presence is defined as "the subjective experience of being in one place or environment, even when one is physically situated in another" (Witmer & Singer, 1998), in line with the notion of *place illusion*.

SUS Presence Questionnaire. The SUS Presence Questionnaire was developed by Slater, Usoh and Steed over a number of studies (Schwind et al., 2019). It aims to measure presence, and consists of 6 items. The items concern a number of different themes, namely the sense of being physically present inside the VE; whether the VE is dominant over the real environment; and whether the VE is remembered as a real, physical place. The items are answered on a 7-point Likert scale, of which 6 and 7 are considered high *scores*. The number of high scores is a representation of the presence score (Slater et al., 1998). When using this questionnaire, the authors describe presence as the sense of being inside the VE.

It is important to note that it is currently under debate whether questionnaires are actually a valid way of establishing presence (Singer & Witmer, 1999; Slater, 1999). Not only are they difficult to validate, they also concern the notion of presence after its occurrence (Mania & Chalmers, 2001), which may influence the data. In addition to this, Slater (1999) has stated that perhaps some presence questionnaires, such as PQ, are more focused on measuring variables thought to co-occur with presence, than the actual subjective feeling of presence.

Physiological measures. Several authors have proposed the use of psychophysiology as measures of spatial presence (Meehan et al., 2002; Pugnetti et al., 2001). The advantage of using physiological measures is that they are objective, and can be measured continuously

(Barfield & Weghorst, 1993; Held & Durlach, 1992; IJsselsteijn et al., 2000). Furthermore, using physiological data in addition to subjective measures, allows for triangulation of data, and may actually reveal effects that are not visible in self-report data alone (Dillon et al., 2002). Physiological measures often used as a representation of presence are heart rate (Dillon et al., 2002; Meehan et al., 2002), electrodermal activity (Dillon et al., 2002; Ravaja, Laarni, et al., 2004), and electromyography (Ravaja, Laarni, et al., 2004).

It is important to note, however, that several issues have been raised about using physiological measures for presence. First, Bouchard and colleagues (Bouchard et al., 2008) reason that, contrary to general beliefs, a sense of presence may actually be related to a *lack* of physiological responses, as a fully natural world does not necessarily evoke much of a physiological reaction. Therefore, a lack of physiological response may not actually reflect a lack of presence, as is sometimes assumed.

Second, and perhaps most importantly, it is the consideration that using physiology as a measure of presence, may bring in a confound of presence and emotions. This is because the same physiological measures are often used to assess emotional arousal (Diemer et al., 2015), and emotional valence (Ravaja, Salminen, et al., 2004), rather than presence. Considering the argument that presence and emotions tend to co-exist, a physiological measure may also reflect the occurrence of presence, but you are likely measuring the emotional experience rather than the presence experience. The difficulty is that such a measure is not able to differentiate between the two. In support of this, there have been a number of researchers which did not find a relationship between physiological data and self-reported presence (Salnäss, 1999; Wiederhold et al., 1998).

Because the studies included in the present systematic literature review do not use physiological measures as a measure of presence, this section will not further elaborate on the

different physiological measurement types. However, it is important to note that any inclusion of physiological measures is subject to the above mentioned discussion of confound.

Behavioral measures. Another way in which presence can be measured, is through the observation of behavior. In order to give an impression of existing behavioral measures, two well-known examples will be provided. However, because studies in the current investigation do not make use of behavioral measures, this section will be kept brief, and further behavioral measures will be disregarded.

One of the most famous behavioral measures of presence is the *startle response*, first coined by Held and Durlach (1992). This measure concerns observing behavioral reactions to visual cues in the environment. If a startling stimulus in a VE is able to evoke a reflex reaction in users, similar to what a real-world reaction would be, then presence is presumed to be evoked.

Another well-known example of a behavioral measure is the *virtual presence counter*, developed by Slater and Steed (2000). When an individual is using VR, and situated within the VE, then they may either experience presence in the virtual world, *or* they may experience a *break in presence*, and instead experience presence in the real world. During a VR session multiple breaks in presence may occur, and Slater and Steed developed a method where the number of breaks in presence are counted, and are used as a reflection of presence experienced.

Emotions

Emotions have been defined as “transient states of feeling” (Freeman et al., 2005). Their onset is typically rapid, they are caused by specific events, they are of short duration, and their intensity depends on individual relevance (Freeman et al., 2005). Furthermore, emotions are considered a common and fundamental aspect of human life (Huang & Alessi, 1999), as they play a vital role in subjective judgments, automatic responses, learning, understanding, guiding

behavior (Huang & Alessi, 1999), guiding human experience, and interpreting events (Riva et al., 2007). Because of this substantial role of emotion, it is important to consider emotions when analyzing a person's interaction with, and experience of, an environment.

Emotion construct

According to the *dimensional theory of emotion,* emotions are thought to be two-dimensional, and have both a *quality* (i.e., valence) and *intensity* (i.e., arousal) (Lang, 1995; Larsen & Diener, 1992). Valence has been described as the (un)pleasantness of the internal affective state (Bradley & Lang, 1994). Arousal has been described as the degree of activation, varying in degrees of excitement (Bradley & Lang, 1994). Emotion often presents itself through autonomic nervous system activation, visible through changes in sweat glands and heart rate (Egeth & Kahneman, 1975; Ekman et al., 1983; Levenson, 1992).

As has become apparent in the current study, there is considerable discussion regarding whether or not presence and emotion are related, and if so, how. One important question presents itself when regarding the dimensional theory of emotion. If presence and emotion are related, on what dimension? Valence, arousal, or both? There are some authors which have suggested that the relationship between presence and emotion may be limited to only the arousal aspect of emotion (Freeman et al., 2005; Meehan et al., 2002). Furthermore, Freeman and colleagues (2005) note that most research on presence and emotions in the past has been on arousing stimuli, and that other results may be found in the case of non-arousing emotional stimuli.

In a study by Ravaja and colleagues, however, a relationship was found between presence and EMG data, which is considered to be a representation of the valence dimensions of emotion (Ravaja, Salminen, et al., 2004). At the time, they were the first study to investigate, and show, the existence of this relationship between presence and emotional valence. Given the

lack of evidence, no conclusion can be drawn regarding on which dimension of emotion the relationship with presence exists, if at all. In order to understand the dynamics between presence and emotion, this is however an important factor to consider, and as such it will be investigated in the current thesis.

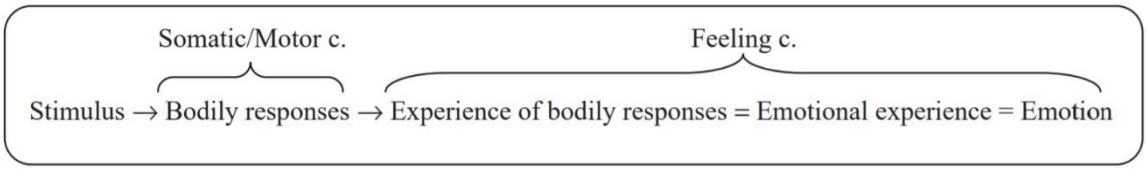
Emotion formation

This section will discuss the best known, most established and most complete theories of emotion formation. A theory is considered complete for the current purpose, if it discusses the complete process of emotion formation, starting from the introduction of a stimulus. In addition, for each theory, a section will be dedicated for the role which presence may or may not have in the formation of emotion, according to the theory. It will follow the same structure as the *presence formation* section, with the goal of understanding how presence could play a role in emotion generation from a theoretical point of view.

James' theory. According to the theory by James (1890), the emotion formation process starts with a stimulus, which directly activates the sensory cortex, and causes bodily reactions in the form of somatic or motor responses. Feedback from the bodily reactions returns to the sensory cortex, where emotion is elicited. Thus, somatic responses come before the emotional experience. In other words, the "emotion experience is nothing but the conscious experience of bodily reactions" (Moors, 2009, p. 12). Furthermore, the quality and intensity of emotions are linked to the quality and intensity of the bodily responses. The specific pattern in somatic and motor responses, causes the specific type of emotion. See figure 1 for an overview of the theory.

Figure 1

Visual representation of James' Theory of Emotion



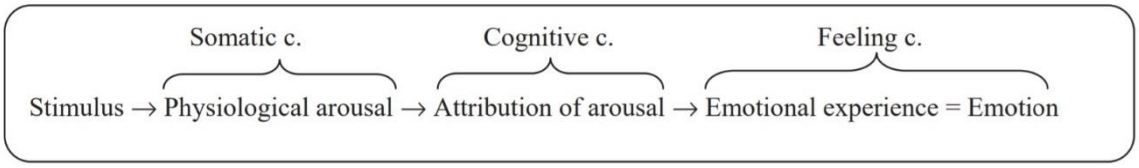
Note. Reprinted from *Theories of emotion causation: A review* (p. 12), by A. Moors, 2009, C*ognition and emotion*, *23*(4), 625-662.

James' theory and presence. The main claim of James' theory, is that emotion is a direct result of physiological signals of the body. The only way in which presence may play a role in the formation of emotion according to James' theory, is if you assume presence itself is able to elicit physiological responses. This ties in with the discussion mentioned in the section *Presence measures,* which is related to whether or not presence in itself is able to evoke physiological changes (Diemer et al., 2015; Ravaja, Salminen, et al., 2004; Salnäss, 1999; Wiederhold et al., 1998). If one assumes presence in itself is able to do so, then according to James' theory one would expect a causal effect of presence on emotion, and hence a correlation. If one assumes presence cannot elicit physiological changes, then according to James' theory one would expect there to not be a causal effect of presence on emotion, nor a correlation.

Schachter's theory. Schachter's theory (Schachter, 1964) consists of two steps. In the first step, a stimulus causes physiological arousal. In the second step, cognitive processes are responsible for interpreting and attributing the arousal. This then causes a specific emotion. To elaborate, the same physiological signal may cause different emotions, depending on the thoughts one has about context of the stimulus. The intensity of the arousal is directly linked to the intensity of the emotion, but it is the cognitive attribution that determines the quality of the emotion experienced. See figure 2 for a visual representation of Schachter's theory.

Figure 2

Visual representation of Schachter's Theory of Emotion



Note. Reprinted from *Theories of emotion causation: A review* (p. 14), by A. Moors, 2009, C*ognition and emotion*, *23*(4), 625-662.

Schachter's theory and presence. According to Schachter's theory of emotion, if a stimulus elicits physiological arousal, then it is the attribution of that arousal that will determine whether an emotion will be experienced, and which emotion that is. More specifically, if an individual is situated in a VE, and if a stimulus in that VE elicits physiological arousal, then it is the following reasoning which determines if an emotion is felt: If presence is low, and someone reasons *That stimulus is not real, I am in a VE*, then emotion may not be formed at all. If presence is high, and a stimulus appears real and relevant, then the reasoning regarding the stimulus might be the same as it would be in real life. Hence, one could argue that presence is likely to correlate with, and have a causal effect, on emotion.

Appraisal theories. There are multiple appraisal theories of emotion in existence (e.g., Arnold, 1960; Frijda, 1986; Lazarus, 1966; Lazarus & Lazarus, 1991; Oatley & Johnson-Laird, 1987; Ortony et al., 1990; Roseman, 1996). Moors (2009) has made an overview of the general agreement among all such appraisal theories, which is presented in figure 3.

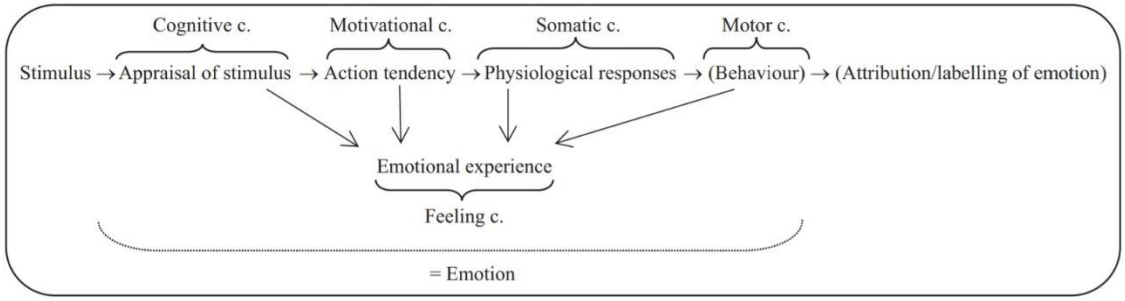
Appraisal theories start with (1) a stimulus, after which (2) *unconscious appraisal of a stimulus* takes place. During the *unconscious appraisal*, it is determined whether or not a certain stimulus will even lead to an emotion. If the process is continued, what follows is (3) *action tendency*, which is a reflection of the motivation to react, elicited by the stimulus. This generally results in (4) a *physiological response*, which prepares the body for behavior that occurs later. After this step, (5) *behavior* follows. After behavior, a *conscious attribution of the emotion* takes

place. This *conscious attribution* is what determines which emotion specifically is experienced. All steps of the process occurring after the stimulus, contribute to the emotional experience, i.e., the feeling component.

Important in this theory, is the realization that there is hardly ever a one-to-one relationship between a specific stimulus and a specific emotion. A specific emotion can be caused by different stimuli, and the same stimulus can lead to different emotions in different individuals. Hence, the range of other factors is necessary to explain emotion. It is generally believed that each specific emotion, is caused by a specific and unique pattern in appraisals.

Figure 3

Visual representation of an Appraisal Theory of Emotion



Note. Reprinted from *Theories of emotion causation: A review* (p. 16), by A. Moors, 2009, C*ognition and emotion*, *23*(4), 625-662.

Appraisal theories and presence. In appraisal theories of emotion, the cognitive appraisal of a stimulus plays a considerable role in the formation of an emotion experience and a feeling. Specifically, it is the *unconscious appraisal*, which takes place when an individual encounters a stimulus, that determines whether or not that stimulus will evoke an emotion. Among others, this may depend on whether an individual considers a stimulus to be *relevant* (Moors, 2009). With regard to presence, one could adopt a reasoning similar to the section *Schachter's theory and presence.* One could argue that perhaps if presence in the VE is low, then

any stimuli encountered in a VE will not be considered real or relevant, which might change the cognitive appraisal process and either diminish or remove the emotional experience. If presence is high however, and the environment and the stimulus *are* considered real and relevant, then the process may continue and the formation of emotion may be facilitated. Following the appraisal theory of emotion, it can be expected that presence has a causal effect on, and hence correlates with, emotion. Additionally, one could argue that perhaps presence is also a pre-condition for emotion to occur.

Network theories. Multiple network theories of emotion exist (e.g., Berkowitz, 1990; Bower, 1981; Lang, 1985; Leventhal, 1980, 1984), but all such theories show certain commonalities (Moors, 2009). First, all network theories assume that emotions are recorded in memory, and that activating these recordings is the cause of the emotional experience. There are two processes inherent to the rest of the theory, namely association/conditioning and semantic networks.

In general, the assumption is that life starts with the ability of certain biologically relevant stimuli to evoke unconditioned emotional reactions. As an individual grows and learns, the range of stimuli that evoke these emotional responses grows, through processes of *conditioning.* All network theories agree, that each time an emotion is experienced, certain information is recorded in memory, such as *information about the stimulus, action tendencies* and *responses*. According to some theories, this recorded information also includes *conceptual meaning* and *emotional experience*. Each time an emotional episode is experienced, all this information is recorded in nodes. For each possible emotion, a schema or network structure of relevant nodes exists.

When a neutral stimulus is encountered, a pairing may take place with an older stimulus already recorded in memory in a specific network structure, already part of an emotional

schema. Pairing tends to take place between stimuli that are either identical or similar, or when the context surrounding the new and the old stimuli are similar. If pairing and co-occurrence takes place repeatedly between the new and old stimulus, then the new stimulus will become associated with, and stored in, the same emotional schema, and thus the existing schema is extended. Then, when at a later stage this stimulus is perceived, then the corresponding emotional schema is activated, and an emotion is experienced. The intensity of the emotion experienced, tends to depend on the strength of the schema activation.

Network theories and presence. It is unsure how presence would relate to the network theory of emotion, however one might argue the following. According to the network theory of emotion, a stimulus is able to evoke an emotional response, if it activates an emotional schema stored in memory. This activation may occur if a new stimulus shows certain similarity to a stimulus already existing in memory, and is paired to it and its corresponding emotional schema. One may argue if the similarity is larger, the pairing might be better facilitated, and hence an emotion might be evoked. In the context of VR, it might be expected that a pairing is better facilitated, if a virtual stimulus in a VE appears more convincing, life-like, and more similar to real stimuli one might have experienced in the past, i.e., if the degree of presence is higher. Within this reasoning, when adopting the network theory of emotion, one might expect that presence facilitates emotion formation, and a causal effect of presence on emotion is expected.

Barrett's conceptual act theory. This theory was developed by Barrett (2006b, 2006a), and it assumes that variables of arousal and valence are the main components of emotional life. Barrett considers them to be properties of stimuli, of the conscious experience, and of neurophysiological states. *Affective quality* is a combination of values of arousal and valence. The affective quality that a certain stimulus might have is what causes the *core affect* in a person, which has both a mental side and a neurophysiological side. Involved in the elicitation of

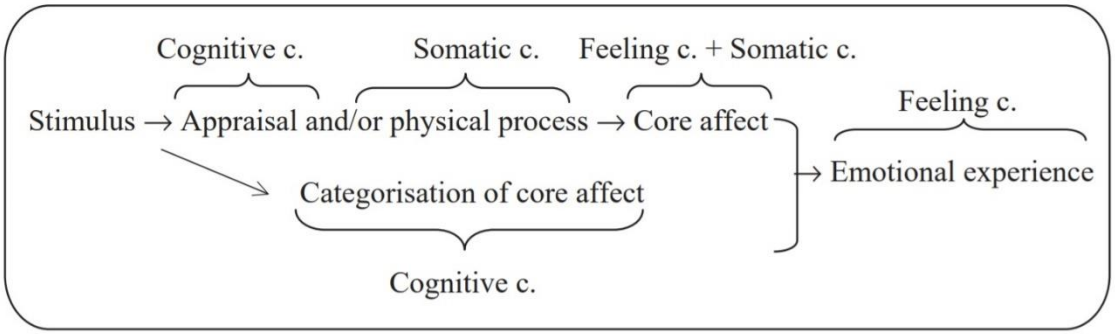
core affect, are factors of both a cognitive and somatic nature, namely processes such as learned and innate associations, rule-based computation, and physical mechanisms (such as being tired).

After *core affect* is formed, an individual subconsciously categorizes it into a specific emotion. This theory states that the classic specific emotions such as sadness and anger are not naturally occurring, and are rather socio-cultural constructions. How a person categorizes a certain *core affect*, depends on the stimulus and on acquired conceptual knowledge. Barrett considers *core affect* and *categorization* to be automatic processes, but not necessarily sequential in nature. The author considers the two to be "two sources of influence that constrain each other until they reach a stable solution" (Moors, 2009, p. 25)

To summarize, Barrett's conceptual act theory is a two-factor theory (Barrett, 2006b, 2006a). In the first factor, a stimulus elicits core affect. In the second factor, core affect is categorized into an emotion, and emotion experience is evoked. Barrett believes that the categorization of core affect happens not before or after the experience, but helps shape the entire experience. See figure 4 for a visual representation of the theory.

Figure 4

Visual representation of Barrett's Conceptual Act Theory of Emotion



Note. Reprinted from *Theories of emotion causation: A review* (p. 25), by A. Moors, 2009, C*ognition and emotion*, *23*(4), 625-662.

Barrett's conceptual act theory, and presence. In the current theory of emotion, there are two steps to the emotion formation. First, a stimulus with an *affective quality* elicits *core affect*. Second, cognition allows for the *categorization* of the core affect, which leads to an *emotional experience*. Whether or not a stimulus with *affective quality* actually elicits *core affect* is partially determined by cognitive appraisals. This leads to a similar reasoning about presence as was conducted in previous sections. More precisely, if presence is high, stimuli in the VE may seem more real and relevant, which may enable *affective quality* to elicit *core affect*. In this reasoning, one would also expect presence to have a causal effect on, and hence a correlation with, emotion. Perhaps presence may even be a pre-condition for emotion to occur.

Philosophical cognitivism. A range of different theories in the area of philosophical cognitivism exist (e.g., Lyons, 1999; Nussbaum, 1990; Solomon, 1993), however generally authors in this domain believe that the formation of emotion is purely a cognitive process (Moors, 2009). Emotions are considered to be caused by, or identical to, judgments of a stimulus. Judgments, in this sense, are considered "mental contents to which one ascribes a truth value" (Moors, 2009, p. 28). An example is, that when an individual believes to have been harmed purposefully, the emotion of anger may be elicited. The cognitive aspect is considered to be not only responsible for the elicitation of emotion, but also for differentiation between emotions. In theories of philosophical cognitivism, somatic and motor responses related to emotions are either neglected, or placed after the formation of emotion.

Philosophical cognitivism and presence. In this theory, judgments and cognitions are solely responsible for the formation of emotions. This indicates the experience of presence to be vital for emotion formation. VEs will only evoke emotions if an individual truly believes to be in that VE, if an individual believes the VE is real, and if individuals believe stimuli in the VE are real. For instance, *fear* will only be experienced in a VE if an individual actually *believes* to be in

danger. Following the philosophical cognitivism approach to emotion, one could argue that presence is a precondition for emotion to occur. That would also mean that has a causal effect on, and thus correlates with, emotion.

Philosophical perceptual theories. Multiple philosophical perceptual theories of emotion are in existence (e.g., Clarke, 1986; Goldie, 2000; Sousa, 1987). As explained by Moors (2009), this area of theories believes that making a distinction between *propositional representations* and *perceptual representations* is vital in the generation of emotion. A *propositional representation* is a thought an individual believes to be true. A *perceptual representation* is a thought an individual does not necessarily believes is true, but entertains anyway. For instance, it is possible to be afraid of flying, without actually believing the plane will crash. In other words, "emotions are not so much judgments, but ways of seeing" (Moors, 2009, p. 29).

More specifically, philosophical perceptual theories believe that emotion is more similar to *perception* than *judgment*. Both emotions and judgments are thought to arise unintentionally, instantly, efficiently, and are difficult to control or negate.

Philosophical perceptual theories and presence. Following the philosophical perceptual theories of presence, there may not actually be much of a relationship between presence and emotion. This theory highlights that emotion may occur, purely based on perception, regardless of what an individual actually believes to be true. This reasoning would entail that a VE may elicit emotions, regardless of whether the individual believes to actually be present in the VE, and thus regardless of whether presence is evoked. Following philosophical perceptual theories of emotion, one would expect that there is neither a causational effect, nor a correlation, between presence and emotion.

Measuring emotion

Measures of emotion come in multiple different categories. They can be of a subjective nature, in the form of self-report measures (Crichton, 2001; Spielberger, 1983; Watson et al., 1988). They can also be objective, in the form of physiological measures (Egeth & Kahneman, 1975; Ekman et al., 1983; Levenson, 1992) and behavioral observations (Ekman, 1994). The ones relevant for the current systematic literature review, will be presented below.

Subjective measures. The subjective measures of emotion most commonly utilized in the studies included in the current systematic literature review, will be discussed below.

Positive and Negative Affect Schedule. Also referred to as PANAS, this scale is a brief 10-item mood scale, developed by Watson and colleagues (Watson et al., 1988). Items are answered on a 10-point scale, ranging from *very slightly or not at all* to *very much.*

The scale is based on a two-factor model, approaching mood through Positive Affect (PA) and Negative Affect (NA). PA is a reflection of "the extent to which a person feels enthusiastic, active and alerts" (Watson et al., 1988). NA, on the other hand, is a reflection of "subjective distress and unpleasurable engagement" (Watson et al., 1988).

State Trait Anxiety Inventory. STAI (Spielberger, 1983) is a measurement of anxiety in adults. It consists of two scales, 20 items each, which can be answered using a 4-point scale ranging from *not at all,* to *very much so*. It differentiates between two types of anxiety, namely *state anxiety* which is of a temporary nature, and *trait anxiety*, which is more general and long-term. It specifically evaluates a number of anxiety-related feelings, such as tension, worry, nervousness and apprehension.

Subjective Unit of Discomfort Scale. The subjective unit of discomfort scale (SUDS), is also sometimes referred to as the *subjective unit of disturbance scale*. It was first developed by Wolpe (1990), and consists of a single item scale of anxiety, to be answered using an 11-point

Likert scale (on a scale of 0 to 100). In this scale, individuals are asked to assess their self-rated current anxiety.

Visual Analogue Scale. VAS is a measure which aims to assess characteristics or phenomena that are hard to quantify, and does so using a visual representation of a continuum (Crichton, 2001). This visual representation could be in the form a vertical line, with labels at each end. It has been used to measure a wide range of factors, and is also commonly used for emotion measurements. The questions to be asked, are designed by the authors who aim to use the scale.

Physiological measures.

Electrodermal activity (EDA). EDA is a measure of electrical activity, measured through secretions and dilations of eccrine sweat glands. Activation of the sweat glands has been associated with the arousal aspect of emotion (Greenwald et al., 1989).

Electrocardiogram (ECG). ECG is a type of physiological measure which records electrical potential associated with heart beats. Heart rate can generally be seen as a reflection of emotional experience, and is thought to be able to reflect both emotional arousal (Healey, 2000) and valence (Healey, 2000; Lang et al., 1993).

Facial Electromyography (EMG). Facial EMG is considered the primary measure of emotional valence (Ravaja, 2004; Tassinary et al., 2009). It records the activity of numerous muscles across the face, and is thought to be able to distinguish between positive and negative emotions (Lang et al., 1993; Larsen et al., 2003; Ravaja, Laarni, et al., 2004), both high- and low-arousal in nature (Ravaja, 2004).

Systematic Literature review

In this part of the thesis, the aim is to investigate the relationship between presence and emotions in VR, by comparing and evaluating the results of the different studies available that report on that dynamic. The decision was made to conduct this evaluation using the Systematic Literature Review (SLR) approach. An SLR has been defined in the past as "a systematic, explicit, comprehensive, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners" (Fink, 2019). The decision was made to apply SLR, because the study designs in this research area tend to differ substantially. Not only are usually a wide range of different specific emotions measured across studies (e.g., fear, sadness), it is also the case that the relationship between presence and emotions is measured in a variety of different ways. This generally complicates comparison, however the SLR allows for such discrepancies, and is yet able to create structure.

The SLR consists of a number of phases, as described by Okoli and Schabram (2010). In phase 1, the *purpose* of the literature review is argued. In the case of the current thesis, the purpose of the SLR is discussed in the *Introduction* and *Literature review* sections, provided earlier. In phase 2, a *protocol* is established. It is essentially the *planning stage* of the SLR. This entails that a clear plan is drafted regarding the execution of the SLR, which includes, for instance, establishing the databases and keyword sets that will be used. Phase 3 is the *literature search.* This is essentially the selection stage of the SLR, in which studies are selected based on inclusion and exclusion criteria. In phase 4, the *practical screen* takes place. In this phase, a researcher considers which studies are actually suitable for review, based on their content. Phase 5 is the *quality appraisal,* in which studies are included or excluded based on quality appraisals deemed important by the researcher. This quality appraisal differs for each SLR, and

no definitive guide for conducting a quality appraisal exists. Phases 2 to 5 will be described in the *method* section below. Phase 5 is then followed by phase 6, *data extraction*. In this phase, data is collected systematically from each relevant article. The data of interest depends on the selected research question. In phase 7, *study synthesis*, the information acquired is aggregated, discussed, organized, and compared. The goal is to make sense of the large amount of data. Lastly, in phase 8, the review is *written*. The last two phases are represented in the *results* and *discussion* section of the current thesis.

Method

Study search and -selection

This section of the thesis concerns an explanation of phase 2 through 5. More specifically, this section will discuss the protocol used (phase 2), it will describe how the literature search took place (phase 3), discuss the practical screen (phase 4), and the quality appraisals adopted (phase 5).

First of all, the *protocol* was established (phase 2). This phase essentially represents the planning that took place beforehand. It starts with the selection of the databases that the source material would be collected from. The decision was made to include numerous databases, as past research has shown the importance of using multiple different databases while doing reviews (Bramer et al., 2013, 2016). The list of databases was constructed in a number of steps.

First, it was investigated which journals are most likely to publish articles relevant to this review, based on the references already acquired in this thesis. Second, it was researched which databases contain said journals. Third, the author's accessibility to the databases was taken into account. Lastly, a number of sources were consulted, to investigate which databases are considered most effective and valuable when conducting reviews (Bramer et al., 2017;

Gusenbauer & Haddaway, 2020). At the end of this process, the decision was made to include *ACM Digital Library*, *PsychArticles*, *SCOPUS* and *Web of Science*.

Three sets of keywords were formulated by investigating the titles, abstracts and keywords of relevant studies already available, and identifying the terms that were most common and essential. The first set of keywords concerned *emotion*. The syntax was constructed in such a way that variations of emotion found in literature were included (e.g., affect, mood, valence, fear). The second keyword concerned *presence*, and the third keyword set constituted a reference to the *media* used (e.g., virtual reality, immersive media). Asterisks were used to ensure different variations of the keywords were included, e.g., emotion* is used to refer to emotional, emotions and emotion. See Figure 5 for the precise keywords used. Based on the already available articles, and on the number of results acquired in the initial search, the decision was made to include studies if the keyword *presence* could be found in the title, and keyword sets related to *emotion* and *media* could be found in the title, abstract, or keywords.

The syntax used was adapted per database, and the number of results were further limited by only including journal articles and proceedings papers, only including results in English, and only including results related to the field of *Psychology* and *Computer science*. See appendix A for an overview of the different specific syntaxes, adapted for each database.

Figure 5

Keywords used for the Systematic Literature Review

Emotion keywords	emotion* OR "affect" OF affective OR affection* OR mood OR arous* OR valence OR anxi* OR fear OR phobi* OR relax* OR joy*
	AND
Presence keywords	presence
	AND
Media keywords	virtual OR media OR mediated OR medium OR computer-generated OR immers*

Note. The keyword sets used for searching the databases. Asterisks were used to include variations of words. Emotion* can refer to: emotion, emotions, emotional. Affection* to: affection, affectionate. Arous* to: arousal, arousing. Anxi* to: anxiety, anxious. Phobi* to: phobia, phobias, phobic. Relax* to: relax, relaxing, relaxed. Joy* to: joy, joyous, joyful.

Studies measuring all manner of different emotions, and applying all manner of different study designs, were included. Studies adopting different variations of the term 'presence' were included, given that their meaning was equivalent to the general notion of presence (see the previous chapter on *Presence*). Subtypes of presence such as co-presence and social presence were not included, as these are phenomenon that tend to be inherently different in nature.

The *literature search* (phase 3) was conducted between July 2020 and August 2020. Initial search across all four databases generated 640 results. For the *practical screen* (phase 4) of the SLR, abstracts and titles were scanned for relevancy to the topic. Furthermore, to account for a *quality appraisal* (phase 5), studies were included if they were responsible for original empirical work; if they purposefully included quantitative measures of both presence and emotion; if they reported which measures they used, and directly reported on the relationship;

and if the type of presence included was relevant to the current study. Irrelevant, unavailable, and duplicate studies were removed, after which a number of 37 articles were left.

Data extraction

In the next phase, the *data extraction* (phase 6) took place. More concretely, the following information was collected for each study. First, the goal of the study. Second, information about the participant pool, namely number of participants, whether the participants originated from a specific clinical group (e.g., specific phobias), mean age, and gender. Third, the type of media involved (e.g., VR). Fourth, the presence term adopted in the article (e.g., telepresence). Fifth, the way presence was conceptualized (e.g., place illusion). Sixth, the measures used for assessing presence (e.g., the presence questionnaire adopted). Seventh, the emotion aspects or -types that were included in the measurements (e.g., valence, anxiety). Eighth, the measures used for assessing emotions (e.g., anxiety questionnaires, heart rate measures). Ninth, the results regarding the emotion-presence relationship. See appendix B for an overview of general information of the studies involved in this SLR. See appendix C for an overview of the content-relation information, and results, of the studies included in this SLR.

In this SLR, the relationship between emotions and presence were investigated in detail. Specifically, it was investigated whether a *correlation* between presence and emotions can be shown, followed by investigations into the existence of a *causal effect of emotion on presence*, *a causal effect of presence on emotion*, and lastly investigations into whether a *circular relationship* between the two exists. In the current data investigation, a *causal effect of emotion on presence* entails that the study of interest manipulated emotion, and reported on the change in presence. A *causal effect of presence on emotion*, entails that the study of interest manipulated presence, and reported on the change in emotion. Lastly, an investigation into whether the *relationship is circular*, entails that a study investigated the effect of a presence

manipulation on emotion, and of an emotion manipulation on presence. Alternatively, a relationship was considered circular if both presence and emotions were measured, and a statistical method (such as linear regression) was able to show that both presence impacted emotion, and emotion impacted presence.

For each direction of investigation, the percentage of studies which found significant results to support the investigation, were compared with the percentage of studies which found insignificant results, and with the percentage of studies which found mixed results. All percentages were rounded to full numbers. Mixed results can be described as studies which found partial support for their investigation, however for which a specific reason can be pointed out as to why results are not fully significant (e.g., there was a specific effect of gender – results were only significant for females, and not for males). The goal of this use of percentages, is simply to provide an idea of the distribution of results across studies, and to show trends that seem to appear in current-day data in the research area of emotions and presence.

Furthermore, in order to get a complete picture of the concept of presence, emotion, and their dynamics in literature, results will be compared, differentiating between the multiple factors of interest mentioned above (i.e., participant population, presence conceptualization, emotions included, presence measure, and emotion measure). The decision was made to look more closely into these variables, because each of them may have had an effect on the data obtained, and understanding their effects may contribute to both the interpretation of the results, and to a better understanding of presence, emotion and their relationship. For instance, there were investigations into the difference in results between studies which use *PQ* to measure presence, as compared to those who use *IPQ*. Another example could be that it was investigated whether the relationship between presence and emotion is the same for the studies investigating *sadness* as compared to studies investigating *anxiety*. In the specific

investigations that will follow, the choice was made to investigate only the most common emotions, presence measurements and emotion measurements in detail, because the number of occurrences of other emotions or measurements was simply too low to draw any meaningful conclusions.

Results

General information

On average, the selected studies have a participant pool consisting of 136 individuals (median = 50). The least number of participants represented in a study is 18, whereas the largest number of participants represented in a study is 2574. Mean age across all studies was 31, of which 3 studies (8%) did not report on the age of their participants. As for gender, the average study had a distribution of 57% female and 43% male participants. Lastly, 11 out of 37 articles (40%) specifically included individuals from clinical groups, of which 5 focused on specific phobias (14%; i.e., social phobia or acrophobia), 5 focused on a form of anxiety (14%; e.g., anxiety disorder or test anxiety), and one focused on eating disorders (3%).

Furthermore, regarding content, 16 out of 37 articles (43%) were directly focused on investigating the link between presence and emotions, whereas the remaining articles had different main topics of interest (e.g., the influence of personality and individual abilities on the sense of presence experienced in anxiety triggering virtual environments). The presence term used most across all studies was *presence* (92%). Other terms were all mentioned once, and included *physical presence* (3%), *mediated presence* (3%) and *spatial presence* (3%).

Out of all 37 studies, 2 specifically conceptualized presence according to the notion of *inner presence* (5%), whereas 31 out of 37 studies conceptualized presence according to the notion of *media presence* (84%), and 3 did not report on their conceptualization or were unclear (8%). The authors of 1 study reported a different conceptualization all-together (3%), namely

related to the level of connectedness one experiences with the environment (Price et al., 2011). Within the 31 studies aligned with the media presence conceptualization, presence was most commonly conceptualized according to the notion of *place illusion* (68%), followed by *illusion of non-mediation* (16%), those who use both aspects to conceptualize presence (10%), and other (7%).

Regarding emotion, the most common emotion measured by studies was anxiety, which was measured 19 times in the current dataset (51%). Other emotion-related variables commonly measured were fear (14%), relaxation (11%), sadness (11%), emotional arousal and valence (8%), and joy (8%).

The most commonly applied presence measures were ITC-SOPI (ITC-Sense of Presence Inventory), occurring 11 times in the current dataset (30%), followed by the IPQ (Igroup Presence Questionnaire; 27%), PQ (Presence Questionnaire; 16%), and the SUS Questionnaire (Slater-Usoh-Steed; 14%). Out of all studies, 6 utilized self-constructed measures (16%).

As for the measurements used to assess emotion, the most common measures were the STAI (State-Trait Anxiety Inventory; 35%), VAS (Visual Analogue Scale; 15%), PANAS (Positive and Negative Affect Schedule; 13%), and SUDS (Subjective Unit of Discomfort Scale; 14%). In 10 studies the authors made (additional) use of physiological measures (27%), namely heart rate in 9 instances (24%), skin conductance in 3 instances (8%), and electromyography (EMG) in 1 instance (3%), sometimes using combinations of physiological measures of emotion.

Content-specific results

General results. In Table 1, the general results across all studies are portrayed. Results show considerable evidence for all directions of the emotion-presence relationship (>68%). Among all investigations, this effect is least strong for studies investigation a correlation between presence and emotion (68%), and a circular relationship (67%), and strongest for

studies investigating the effect of emotion on presence (80%), and of presence on emotion (77%).

Table 1

General results across all studies

Direction	% Sign.	% Insign.	% Mixed	# Studies
Correlation	68%	14%	19% [1-3,5-8]	37
E -> P	80%	7%	13% [1,7]	15
P -> E	77%	8%	15% [3,8]	13
E <-> P	67%	17%	17% [4]	7

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. Direction = Direction of the emotion-presence relationship investigated. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Circular effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Results per participant pool. Because of the current thesis' interest in the dynamics between presence and emotions, it became natural to include numerous studies which explored VR as a method for exposure therapy (VRET), as both presence and emotions are inherent to the context of VRET. The difficulty with this however, is that you introduce a number of studies with quite specific participant populations, as these types of studies are especially interested in participants with a certain clinical background (for instance suffering from phobia). It may be presumptuous to assume that the presence-emotion dynamics are the same for individuals with and without a mental disorder. The reason for this section is to see whether there is a difference

between the studies using clinical and non-clinical groups, and whether perhaps a confound is introduced by including a large number of VRE studies.

Out of 37 studies, there are 11 studies with participants specifically selected from some sort of specific clinical pool (e.g., diagnosed with anxiety, a specific phobia or an eating disorder), and 26 studies with a nonspecific participant pool. It would firstly be interesting to see whether there is a difference in results between these two groups. See Table 2 for the most important results in this investigation.

Here it becomes apparent that evidence for most directions of the presence-emotion dynamic is strongest in studies using *nonspecific pools.* This is especially the case regarding the correlation between emotion and presence (73% versus 55%), for an effect of emotion on presence (E->P; 89% versus 67%), and for a circular relationship (E<->P; 75% versus 50%). For studies with *clinical participant pools*, specifically the evidence for a *correlation* and for a *circular* relationship is notably weaker (around 50%). On the other hand, evidence for an effect of presence on emotion (P->E) is considerably stronger among VRET studies (100% versus 73%).

Table 2

Results across studies including participants from clinical groups *versus* nonspecific groups

Participant group	Correlation				E -> P				P -> E				E <-> P			
	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies
Clinical	55%	27%	18% [1,2]	11	67%	17%	17% [1]	6	100%	0%	0%	2	50%	0%	50% [4]	2
Non-clinical	73%	8%	19% [3,5-8]	26	89%	0%	11% [7]	9	73%	9%	18% [3,8]	11	75%	25%	0%	4

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Circular effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Furthermore, it could be relevant to make a distinction within the different clinical pools included. Out of these 11 studies, 5 included participants diagnosed with an anxiety-type disorder (e.g., test anxiety, social anxiety), 5 with a specific type of phobia (e.g., social phobia, acrophobia), and 1 included participants with eating disorders. See Table 3 for an overview of the results comparing these studies.

These results generally show that studies using participants with *anxiety* and *eating disorders* have most consistent evidence for all directions of the emotion-presence relationship (60-100%), though it should be noted that among studies including participants with an anxiety disorder, evidence for a correlation is relatively low (60%). For studies including participants with *phobias*, evidence appears considerably weaker, especially regarding the *correlation* between presence and emotion (40%), the effect of emotion on presence (E->P; 33%), and the circular relationship (E<->P; 0%).

Table 3

Results across studies, categorized according to studies including participants with anxiety, phobia and eating disorder

Participant group	Correlation				E -> P				P -> E				E <-> P			
	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies
Anxiety	60%	20%	20% [5]	5	100%	0%	0%	3	100%	0%	0%	1	100%	0%	0%	1
Phobia	40%	40%	20% [1]	5	33%	33%	33% [1]	3	100%	0%	0%	1	0%	0%	100% [4]	1
Eating-disorder	100%	0%	0%	1												

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Circular effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Results per presence conceptualization. As has become apparent throughout the current article, there is still considerable discussion regarding the nature of presence, and numerous conceptualizations of the presence concept exist. There is limited consensus regarding which conceptualization is or is not correct, nor is it known how the different conceptualizations relate to each other. Therefore, in order to better understand presence research, specifically related to emotion, it may prove interesting to investigate any differences in the results obtained, based on the presence conceptualization adopted by the authors in their article. It can be argued whether or not it matters which definition of presence is provided in a text, however it should be considered that the way in which an author defines presence may, subconsciously or otherwise, alter the way in which they design their study and interpret the results. This section was included to control for that.

As was previously stated, 2 out of 37 studies conceptualized presence according to the notion of *inner presence*, and 31 out of 37 conceptualized according to the notion of *media presence*. See Table 4 for the differences in results based on these conceptualizations. In general, it becomes apparent that for most directions of the presence-dynamic, evidence is strongest in the media presence group (>67% versus >50%). This is specifically the case for studies investigating a correlation (68% versus 50%), and those investigating the effect of presence on emotion (P->E; 80% versus 50%). For both those investigations, in fact, evidence among *inner presence* studies is unconvincing (50% in both cases). For an effect of emotion on presence, however, the *inner presence* studies find strongest evidence (100% versus 83%).

Table 4

Results across studies, categorized as studies adopting inner presence *and* media presence *conceptualizations*

Presence conceptualization	Correlation				E -> P				P -> E				E <-> P			
	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies
Inner presence	50%	0%	50% [8]	2	100%	0%	0%	1	50%	0%	50% [8]	2				
Media presence	68%	16%	16% [2,3,5-7]	31	83%	8%	8% [7]	12	80%	10%	10% [3]	10	67%	17%	17% [4]	6

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Bidirectional effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Furthermore, it might be interesting to make a distinction between the different conceptualizations *within* the media presence group. Specifically, there were 21 studies which conceptualized according to the notion of *place illusion,* 5 that conceptualized according to *non-mediation*, and 3 who believe *illusion of non-mediation* is central, but *place illusion* is also naturally implied. See Table 5 for an overview of the most important results comparing conceptualizations within the media presence group.

Generally, results show that studies which define presence as both a *place illusion* and a *non-mediation illusion* (i.e., *combination*) find strongest evidence for all directions of the emotion-presence relationship (100%), followed by those that conceptualize according to *place illusion* (25-83%), and lastly those that conceptualize according to *non-mediation illusion* (20%).

Table 5

Results across studies, categorized as studies adopting conceptualizations of illusion of non-mediation, place illusion *and* a combination of the two

Presence conceptualization	Correlation				E -> P				P -> E				E <-> P			
	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies
Place illusion	76%	14%	10% [6,7]	21	80%	10%	10% [7]	10	83%	17%	0%	6	25%	50%	25% [4]	4
Non-mediation	20%	40%	40% [2,5]	5												
Combination	100%	0%	0%	3	100%	0%	0%	1	100%	0%	0%	2	100%	0%	0%	1

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Bidirectional effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Results per emotion type. As has been highlighted in the current article before, there is not only discussion regarding *whether* a relationship between emotions and presence exist, but also regarding whether this correlation exists for all emotions, regardless of their arousal and valence levels. Understanding how specific emotions interact with presence, will improve understanding of their dynamics.

With regard to the specific types or aspects of emotions measured, the most common ones adopted by studies, as discussed earlier in the section *General information*, will be investigated below. More specifically, this includes investigations of anxiety, fear, sadness, relaxation, joy, and arousal/valence. It should be noted that some studies investigated multiple emotions, and, as such, some of the results might overlap. See Table 6 for the most important results, categorized by the most common emotions investigated.

In general, this investigation shows that there is evidence for practically all directions of the emotion-presence relationship, for practically all emotions. However, for the emotions *anxiety* and *fear*, results are somewhat more mixed. For the emotion *anxiety*, evidence for a correlation is questionable (55%). Evidence for an effect of emotion on presence (E->P; 75%) and presence on emotion (P->E; 86%) is still present, but relatively less relative to other emotions. For *fear*, evidence of an effect of presence on emotion (P->E; 67%) is limited, and for a circular relationship is questionable (E<->P; 50%).

Table 6

Results across studies, categorized according to the emotion aspect measured

Emotion measured	Correlation				E -> P				P -> E				E <-> P			
	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies
Anxiety	55%	25%	20% [1,2,6,8]	20	75%	13%	13% [1]	8	86%	0%	14% [8]	7	100%	0%	0%	3
Fear	100%	0%	0%	5	100%	0%	0%	2	67%	33%	0%	3	50%	0%	50% [4]	2
Sadness	100%	0%	0%	4	100%	0%	0%	1								
Relaxation	100%	0%	0%	4	100%	0%	0%	2	100%	0%	0%	3	100%	0%	0%	1
Joy	100%	0%	0%	3												
Arousal/valence	67%	0%	33% [5]	3	100%	0%	0%	1								

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Bidirectional effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Results per presence measurement. The decision was made to make a distinction between the different presence measurements used in the studies. This is especially interesting, considering each presence measure makes certain implicit assumptions about the nature of presence, and the way it is shaped. Understanding which measures do or do not tend to find significant results, and understanding the assumptions each of the measures make, could contribute to our understanding of the concept of presence, and of its dynamics with emotions.

All presence measurements in the relevant studies were subjective self-report measures. The most common ones, as discussed in the sub-chapter *General information,* will be separately discussed below. To be more precise, this includes ITC-SOPI, IPQ, PQ and SUS. It should be noted that some studies applied multiple measures of presence, as such some of the results below might overlap. See Table 7 for the most important results, categorized per presence measure used.

Generally, results are quite mixed. The presence measure that shows most robust evidence for all directions of the emotion-presence relationship is ITC-SOPI (80-100%). The presence measure associated with most varying results is the *PQ*, specifically with regards to evidence for a correlation (50%), and evidence for an effect of emotion on presence (E->P; 33%).

Table 7

Results across studies, categorized according to most common presence measures adopted

Presence measure	Correlation				E -> P				P -> E				E <-> P			
	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies
ITC-SOPI	82%	0%	18% [5,8]	11	100%	0%	0%	6	80%	0%	20%	5	100%	0%	0%	2
IPQ	70%	20%	10% [2]	10	100%	0%	0%	3	100%	0%	0%	2	0%	0%	100% [4]	1
PQ	50%	50%	0%	6	33%	67%	0%	3	100%	0%	0%	2	100%	0%	0%	1
SUS	80%	20%	0%	5												

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Bidirectional effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Presence per emotion measurement. Lastly, the decision was made the compare results across studies based on the emotion measurement adopted. It has become apparent earlier, that there is a considerable difference between the emotion measurements, in terms of how they are designed, and the emotion (aspects) they measure. Comparing how the different emotion measurements relate to each other in terms of results, can once again contribute to the understanding of the presence-emotion dynamics, and contribute to increased understanding of data.

Most studies investigated emotion using subjective self-report questionnaires. As was discussed in the sub-chapter *General information* above, the most common ones are STAI, VAS, PANAS, and SUDS, which will be highlighted below. It should be noted that some studies applied multiple measures of emotion, as such some of the results below might overlap. See Table 8 for the most important results, categorized by the multiple emotion-related subjective self-report questionnaires used.

Results generally show most robust evidence for all directions of the emotion-presence relationship in studies adopting emotion measures of either VAS or PANAS (100%). Regarding STAI and SUDS, results are more mixed. Typically, studies adopting the emotion measure STAI show less evidence for a correlation between presence and emotion (55%), and evidence for a circular relationship is relatively low (67%). For studies adopting SUDS, evidence for an effect of emotion on presence is less strong relative to the other measures (E->P; 67%), and evidence for a circular relationship is limited (E<->P; 50%).

Table 8

Results across studies, categorized according to most common subjective emotion measures adopted

Emotion measure	Correlation				E -> P				P -> E				E <-> P			
	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies
STAI	54%	15%	31%[1,2,6,8]	13	86%	0%	14%[1]	7	71%	14%	14%[8]	7	67%	33%	0%	3
VAS	100%	0%	0%	6	100%	0%	0%	2	100%	0%	0%	3	100%	0%	0%	1
PANAS	100%	0%	0%	5	100%	0%	0%	2	100%	0%	0%	3	100%	0%	0%	1
SUDS	80%	20%	0%	5	67%	33%	0%	3	100%	0%	0%	3	50%	0%	50%[4]	2

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Bidirectional effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Furthermore, it is important to note that subjective self-report questionnaires were not the only method of emotion measurement adopted. When looking at emotion measures, it is possible to make a distinction between results obtained using only subjective self-report measures, those obtained using only objective physiological measures, and results obtained through a combination of the two. See Table 9 for a comparison of results among these category.

For this comparison, results show that evidence for all directions of the emotion-presence relationship is most robust when studies make use of only subjective self -report measures (71-100%). When they make us of objective measures, or a combination of the two, results are relatively limited. This is especially the case for studies investigating the correlation between presence and emotion (50%), the effect of presence on emotion (P->E; 33%), and the circular relationship (0%).

Table 9

Results across studies, categorized according to studies adopting subjective measures of emotion*,* objective measures of emotion*, and a* combination *of the two*

Emotion measure	Correlation				E -> P				P -> E				E <-> P			
	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies	% Sign.	% Insign.	% Mixed	# Studies
Subjective	71%	12%	15%[1,3,6,7]	26	80%	0%	20%[1,7]	10	90%	0%	10%[3]	10	100%	0%	0%	4
Objective	50%	50%	0%	2	100%	0%	0%	1								
Combination	50%	25%	25%[2,8]	8	67%	33%	0%	3	33%	33%	33%[8]	3	0%	50%	50%[4]	2

Note. All percentages are rounded to full numbers. % Sign. = Percentage of studies which reported significant results. % Insign. = Percentage which reported insignificant results. % Mixed = Percentage which reported mixed results. # Studies = Number of studies which reported on the investigation. E -> P = Effect of emotion on presence. P -> E = Effect of presence on emotion. E <-> P = Bidirectional effect between presence and emotion. Superscripts are references to the specific mixed results of interest, as portrayed in appendix D.

Discussion

Presence is a phenomenon which is considered vital to the effectiveness, enjoyment, and experience of VR (Baños et al., 2004; Baños et al., 2008; IJsselsteijn et al., 2006; IJsselsteijn & Riva, 2003; Larsson et al., 2001; Schuemie et al., 2001; Tussyadiah et al., 2018). Years of research have tried to identify factors that may influence, enable or stimulate the formation of presence (Hendrix & Barfield, 1996; Huang & Alessi, 1999; IJsselsteijn et al., 2001; Welch et al., 1996). Only recently, an important variable was identified that was initially disregarded in presence research, namely emotion (Alsina-Jurnet et al., 2011; Baños et al., 2004; Botella et al., 2007; Bouchard et al., 2008; Price et al., 2011; Price & Anderson, 2007; Robillard et al., 2003). Due to an initial disregard of emotion in presence research (Huang & Alessi, 1999), and due to the complicated nature of presence, there is limited clarity regarding whether or not a relationship between emotion and presence exists in literature, and if so, what this relationship looks like.

The goal of this thesis is to provide an overview of the current-day view in literature of the concept of presence, emotions, and the relationship between presence and emotions, using a literature review and a systematic literature review. To the knowledge of the authors, this is the first paper to provide such an overview of the literature regarding the relationship between emotion and presence. Specifically, the main research question was *What is the general consensus in literature regarding the relationship between presence and emotions?* This question was approached using a number of sub-questions.

Literature review

The first sub-question to answer was *What are the current theories regarding presence, emotions, and the relationship between presence and emotions?* This question was answered using a regular literature review.

When investigating the concept of presence, a number of things became apparent. First, it is a complex phenomenon, described from numerous different theoretical points of view, leading to a clear lack of coherence in literature (Lee, 2004). Having said that, there appears to be a distinction between different types of presence conceptualizations; namely, those who conceptualize presence as *inner presence*, and those who choose the approach of *media presence* (Villani & Riva, 2008).

The most important difference between the two, is that researchers from the *media presence* group are critiqued by *inner presence* theorists for investigating the phenomenon of presence in light of interaction with a media technology only, and are said to be mostly concerned with cognitive and media factors (Villani & Riva, 2008). Those from the *inner presence* group view presence as a common biological human experience independent of technology, and are mostly interested in psychological and ecological factors (Villani & Riva, 2008).

Furthermore, within the media presence group, a distinction can be made between definitions *place illusion* (Steuer, 1992), the *illusion of non-mediation* (Lombard & Ditton, 1997), and a third definition which states *place illusion* is a natural consequence of the *illusion of non-mediation* (Lombard & Ditton, 1997; Slater et al., 1994). It is important to note that while all different conceptualizations, from both the inner presence and media presence groups, consider presence to be formed differently, all are likely to be explaining the same phenomenon at least to some extent. Both cases are about whether or not an individual attributes a (virtual) environment to be real and relevant, and whether they believe to actually be situated inside it.

For both the *inner presence* and *media presence* groups, theories regarding presence formation are provided, and the possible role of emotion in those theories is discussed. For an in-depth discussion of the theories, see the *Presence* section of this thesis. In short, there are a number of theories of presence formation in which emotion may enhance or facilitate presence.

In one instance, emotion may accomplish this by increasing attention(al arousal) to the VE, such as in the *three-layer evolutionary model of presence* (Riva & Waterworth, 2003) or the *spatial situational model of presence* (Wirth et al., 2007). In another instance, emotion may facilitate presence by meeting an individual's emotional expectations about an environment, as theorized in line with the *interoceptive predictive coding model of presence* (Seth et al., 2012). There are also those who believe presence is supported by situated affordances and successful (inter)actions within the VE, to which emotion is not at all related, e.g., the *embodiment framework* (Haans & IJsselsteijn, 2012) and *ecological framework of presence* (Flach & Holden, 1998; Schuemie & Van der Mast, 1999; Zahorik & Jenison, 1998).

Emotion is thought to be a two-dimensional construct, consisting of a *quality* (i.e., valence), and *intensity* (i.e., arousal) (Lang, 1995; Larsen & Diener, 1992). Numerous theories regarding the formation of emotion exist, and for each theory the possible role presence may have in that formation is discussed. In general, theories concern an interplay between stimuli, physiological signals, judgments, and attributions. For a complete overview of all emotion theories, see the *Emotion* section of this thesis.

There are numerous theories in which judgments and attributions are central to the formation of emotion. In those theories, presence may be able to have a causal effect on emotion, and may even be a precondition for emotion to exist, by making stimuli in VEs seem real and relevant. These theories are *Schachter's theory of emotion* (Schachter, 1964), the *appraisal theory* (Moors, 2009), *Barrett's conceptual act theory* (Barrett, 2006a, 2006b), *philosophical cognitivism* (Moors, 2009), and *network theories of emotion* (Moors, 2009). Theories in which presence is likely *not* to have an effect on emotion formation, are *philosophical perceptual theories* (Moors, 2009), and possibly *James' theory* (James, 1890).

Systematic literature review

The next results to consider, are those acquired in the SLR. This section will aim to answer a number of sub-questions described at the beginning of this thesis, namely *What is the existing empirical evidence regarding the relationship between presence and emotions? How do the different empirical findings compare to each other, in light of their theoretical foundations?*

In order to answer these questions, a general overview of results across studies will be provided and explained. Specifically, these include the results regarding (1) the correlation between presence and emotion, (2) the causal effect of emotion on presence, (3) the causal effect of presence on emotion, and (4) the existence of a circular relationship. Furthermore, this section will perform more detailed investigations into the influence that some factors may or may not have had on the data.

As a reminder, for each investigation, the percentage of relevant studies which found significant results, is compared to the percentage of studies which found insignificant results, and to the percentage which found mixed results. Mixed results are results in which evidence for a certain investigation is only partially found, and in which a certain factor or circumstance can be appointed which led to the lack of significant results. In case there are mixed results that appear to have added value in explaining the data obtained, for instance if the percentage of mixed results in a certain investigation is high and the reason for the mixed result is applicable, then such results may be mentioned and discussed. The goal of this SLR is to make current-day trends visible in the research area of presence and emotion.

General results

The first step of the review was to consider the general results, taking into account all studies included. The majority of studies found evidence all directions of the emotion – presence relationship. More specifically, a majority of studies found evidence for the existence

of a correlation between presence an emotion (68%), for a causal effect of emotion on presence (80%), for a causal effect of presence on emotion (77%), and for a circular relationship (67%).

An example of how presence may impact emotion is proposed by Peperkorn, Diemer, and Mühlberger (2015), who were interested in investigating the dynamics between presence and fear in VR. They exposed participants with arachnophobia (fear of spiders) to a virtual image of a spider, either in a monoscopic (low presence) or stereoscopic (high presence) condition. Presence (as measured by the IPQ) was found to increase the sense of fear experienced (as measured by SUDS).

Another example, this time regarding how emotion may affect presence, is a study by Cadet and Chainey (2020). This study was mostly interested in the relationship between emotions, presence, and episodic memory. Participants were shown images of either positive, negative, or neutral stimuli, with the goal of memorizing them. The authors found the emotional quality of the images to increase the sense of presence, as measured by the ITC-SOPI questionnaire.

To summarize, the causal effects of emotion on presence (E->P) and presence on emotion (P->E) were most convincing (>75%). Evidence for a correlation and circular relationship was less convincing, but above chance level nonetheless (>67%). There are two things especially interesting about this data. First, there is generally a higher consensus on a causal effect of emotion on presence (80%), and a causal effect of presence on emotion (77%), as compared to a correlation between the two (68%). This is interesting to note, because when there is a causal effect, a correlation is naturally implied, however studies interested in purely correlational effects find less convincing results.

This may be at least partially explained due to the high number of studies which found mixed results. For all studies investigating correlations, this percentage of studies which found

mixed results is 19%, which is higher than was found in the specific causal investigations (13%, 15%, 17% respectively). This could be part of an explanation, as mixed results generally provide partial support for their correlational assumptions, even though they are not counted as such in the current set-up.

The high number of mixed results does not fully explain the trend in the data however, as among all studies investigating correlations, the number of studies finding clear *insignificant* results, and hence data *not* supporting the correlation (14%), is higher than in the causality investigations (E -> P: 7%; P -> E; 8%). Another explanation could be the fact that, as previously mentioned, a number of studies were included which were not necessarily interested in investigating the relationship between presence and emotion per se, and had different main goals to their study. This number of studies is likely to be higher in the pool of all studies looking at correlations, than in the pool of studies investigating causality, as causality investigations, and the required manipulations needed, portray a higher interest in the emotion-presence dynamics. Furthermore, to finish the reasoning, there might be an inherent difference in results between studies which were not necessarily interested in emotion-presence dynamics, and those specifically aiming to investigate those dynamics.

A second interesting trend in the data, was that there was only moderately convincing evidence for a circular relationship between presence and emotion (67%). This is especially surprising, because evidence for a causal effect of emotions on presence (80%), and for a causal effect of presence on emotions (77%), was evidently stronger, appearing to imply the existence of a circular relationship. This surprising finding may be due to the fact that there was only a limited number of studies (6 out of 37) that actually directly investigated the existence of circularity in their study, highlighting the fact that this finding may not be robust, and skewed results may have been obtained.

Furthermore, there may be another reason why there is more evidence for a causal relationship in both directions, but not necessarily for a circular relationship. Namely, the circular relationship between presence and emotions may exist, but may be more complex. For instance, in one study they found that there were certain temporal dynamics between presence and emotion. Specifically, they found that presence had a causal effect on emotion in early stages of the experiment, and only later this developed into a reciprocal dependency (Peperkorn et al., 2015). Such specific dynamics, temporal or otherwise, may not be well represented in the current dataset, and hence be less visible.

When viewing these results, an important question to ask is, how do these findings relate to the available literature? In terms of presence theories, the results found coincide with the *three-layer evolutionary model* of (inner) presence (Riva & Waterworth, 2003), the *interoceptive predictive coding model* of (media) presence (Seth et al., 2012), and the *spatial situational model* of (media) presence (Wirth et al., 2007). In these theories, emotion may facilitate presence formation by contributing to attention(al arousal) (Riva & Waterworth, 2003; Wirth et al., 2007), or by meeting certain phenomenological expectations one may have of an environment (Seth et al., 2012). Support was not necessarily found for the *ecological view* of (media) presence (Schuemie & Van der Mast, 1999), and the *embodiment framework* of (media) presence (Haans & IJsselsteijn, 2012). It should be noted however, that the current findings do not disregard the ecological view and embodiment framework of presence necessarily. It may still be the case those theories of presence formation are correct, but have perhaps not considered the possible role of emotion.

In terms of emotion theories, the current data obtained supports *Schachter's theory* (Schachter, 1964), the *appraisal theory* (Moors, 2009), *Barrett's conceptual act theory* (Barrett, 2006a, 2006b), *philosophical cognitivism* (Moors, 2009), and *network theories* (Moors, 2009).

Generally, these theories rely heavily on cognitive appraisals and (unconscious) judgments of stimuli in the generation of emotion, which requires an environment, and stimuli inside the environment, to be perceived as real and relevant. Data does not support *philosophical perceptual theories* of emotion (Moors, 2009), because their statement is clear in that a perception does not have to be perceived as real to evoke an emotion. It cannot be determined whether *James' theory* of emotion (James, 1890) is supported. Data shows a clear correlation between presence and emotion, and a causal effect of presence on emotion. In James' theory, this would only be possible if presence itself is able to evoke a physiological response. In later investigations, the link between presence and physiological signals is investigated, which may provide more insight into the support for James' theory.

Results per participant population

As was highlighted before, the current SLR naturally included studies investigating the suitability of VR as a method for exposure therapy (VRET). This introduced a number of studies with quite specific participant populations, as these types of studies are especially interested in participants with a certain mental health condition. This section discusses the kind of effect this may have had on the data.

Clinical versus nonspecific participant pools. Firstly, one could consider whether there is a difference between studies including participants from a certain *clinical* group (11 studies), versus studies including *nonspecific* participants (26 studies).

It appears that in the *nonspecific* group, evidence is high and consistent (>72%) for all directions of the relationship between emotions and presence (correlation, emotion -> presence, presence -> emotion and circularity). In the *clinical* group, the only convincing evidence is for the causal effect of emotion on presence (67%), and presence on emotion (100%), the rest is around chance level.

The first thing to say, is that in the *clinical* group, rather than the *nonspecific* group, the surprising data pattern from the general results has emerged, and appears to be even more pronounced. As a reminder, this odd pattern is that a larger amount studies support the causal effect of emotion on presence, and of presence on emotion, but less so the correlation or circular relationship. This is despite the fact that one may expect that a correlation and circular effect is naturally implied in the causality results. One may argue that the studies including participants from a *clinical group* are the reason for the odd data pattern, not the studies with *nonspecific* participants. This could indicate that the results obtained from studies using participants from *clinical groups* are not necessarily generalizable to other populations, and that including them may add to skewed results.

In the previous section, one argument for the unexpected correlational results, was that this may be because of a large number of studies not specifically interested in presence or emotion, potentially influencing the results. However, that no longer holds true under the current circumstances, because a majority studies from the *clinical group,* investigating VRET, tend to have a strong focus on presence and emotion. The reason for the unexpected correlational result remains unknown.

The reasoning with regard to a lack of evidence for a circular relationship, as provided above, was twofold, both of which still hold with regard to the *clinical group* findings. The first reasoning, is that the number of studies investigating the circular dynamics between presence and emotion is considerably less, hence results are expected to be less robust. The second reasoning, is that the circular dynamic between presence and emotion may be (temporally or otherwise) more complex. In the circular investigations by the *clinical* group, the mixed results were once again due to the aforementioned effect of time (Peperkorn et al., 2015). While it is

impossible to make any claims based on the findings of a single study, it may still be an indication of emotion-presence dynamics.

At first glance it appears to be surprising that the general evidence for dynamics between presence and emotion is stronger and more consistent for the *nonspecific* group. There are numerous studies which found that the relationship between presence and emotion is especially strong among phobic participants (Price & Anderson, 2007; Robillard et al., 2003), which are naturally included in the *clinical* participant pool. However, no such popular conceptions exist regarding the other mental health disturbances included (anxiety and eating disorder), which are of course responsible for a part of the results. In the following section, comparisons will be made between within the studies including clinical participants, in order to see the dynamics between the different mental disturbances.

Anxiety versus phobia versus eating disorder. This section considers what kind of differences there are between the different participant pools of a clinical nature, investigating studies including participants with a form of anxiety, phobia, or eating disorder. It is important to note that this group of studies is limited in size (11 studies in total), hence any investigations, especially of a specific nature, are bound to lack some robustness.

Studies involving participants diagnosed with a form of *anxiety* found most consistent evidence for all directions of the emotion-presence. Evidence for a correlation was 60%, however evidence for all other causal investigations was at 100% (E->P, P->E, E<->P). The study including participants with an *eating disorder* was in agreement, and found evidence for a correlation (100%), however did no further causal investigations. Studies involving participants diagnosed with a *phobia* displayed the most varying results.

For studies involving participants with a phobia, there was only evidence for a causal *effect of presence on emotion* (100%). This entails that if presence is experienced, then this has a

direct effect on the emotion experienced in phobic individuals. Generally, limited evidence was found for a correlation (40%), for a causal effect of emotion on presence (33%), and for a circular effect (0%).

Most surprising is the lack of correlational evidence, because a causal effect of presence on emotion naturally implies the existence of a correlation. Because the percentage of studies which found *insignificant* results, mixed results cannot begin to explain this finding. This data trend seems to be reoccurring throughout the data set, and currently no explanation is available.

It is surprising, that out of all investigations using participants with a clinical background, those targeting phobic participants find most varying results regarding the presence-emotion investigations. This is especially notable, considering several studies have found that emotion-presence dynamics are stronger for phobic participants (Price & Anderson, 2007; Robillard et al., 2003). One possible explanation for this finding is briefly proposed by Robillard and colleagues (2003). The authors mention that phobic individuals may be more inclined to avoid the experience of feeling anxious, and try to block presence by focusing on aspects of the VE that highlight its virtual and artificial nature of stimuli.

Results per presence conceptualization

Media presence versus inner presence. Next, a distinction was made between the studies adopting different presence conceptualizations, in order to investigate if there are considerable differences between the two groups of theorists. A first comparison was made between studies of the *inner presence* and *media presence* group. It is vital to note that there were only 2 studies in the entire pool of 37 studies, that acknowledged conceptualizing presence according to the notion of *inner presence,* versus 31 studies that adopted the notion of *media presence*. This

large discrepancy is likely due to the decision of *inner presence* theorists to distinguish themselves from the rest, but it makes it hard to compare or draw any conclusions either way.

In the case of *media presence*, evidence over all causal relationships seems more stable. For all directions, be it correlation, emotion on presence, presence on emotion and a circular relationship, evidence is considerably above chance level (>66%). Especially for the causal effect of emotion on presence, and presence on emotion, evidence is high (>80%). For the inner presence group, the only evidence found that is considerably high, is for the effect emotion on presence (100%), the rest is at chance level.

In both investigations into the correlation and the effect of presence on emotion*,* within the *inner presence* group, the low percentage of significant results can be explained by the high percentage of mixed results. Given the low number of studies even adopting *inner presence* as their presence conceptualization, in both cases these mixed results are caused by one singular study. In these mixed results, there was an effect of experimental condition, in which a significant correlation was found inside VR, but not in real-life (Villani et al., 2012).

In other words, if one conceptualizes presence according to the notion of *inner presence*, then a causal effect of emotion on presence is supported. When looking at the *three-layer evolutionary model of inner presence*, this is to be expected (Riva & Waterworth, 2003). Emotion is thought to increase attention and arousal, which contributes to the formation of presence. However, a correlation, and a causal effect of presence on emotion, are only found in the VR condition, as compared to the real-life condition. Following the three-layer evolutionary model, an explanation could be that VR in itself is able to generate more arousal than real-life (Estupiñán et al., 2014), thus increasing the sense of presence (Riva & Waterworth, 2003). This would allow for the emergence of the causal effect of presence on emotion, and the emergence of a correlation.

Lastly, it is interesting to note, that within the media presence group, the same trend across data can be seen as in the general results, in which evidence for the causal effect of emotion on presence, and presence on emotion, is higher than evidence for a correlation or circular relationship. This is of course to be expected, as among the total pool of studies, those adopting media presence conceptualizations constitute 95%, thus trends in data are expected to carry over.

Place illusion versus illusion of non-mediation. Continuing with the different presence conceptualizations, it was investigated whether there was a considerable difference within the media presence group, specifically those that indicate presence can be defined as *place illusion* (21 studies), *illusion of non-mediation* (5 studies), and those that define presence as a *combination* of the two (3 studies). Given the large discrepancy in the number of studies included in each group, it is important to consider that the data emerging from the studies adopting place illusion is likely to be considerably more robust.

The *combination* group found strongest evidence of all groups, for all investigations of the relationship between presence and emotion (i.e., the correlation, causal effects and circular relationship) (100%). The *place illusion* group agrees mostly, and finds strong significant results for a correlation, effect of emotion on presence, and of presence on emotion (>75%), but not for a circular relationship (25%). Regarding the *illusion of non-mediation* group, they generally do *not* even find significant evidence for a correlation (20%), and conduct no further investigations.

It is important to note that among studies adopting *illusion of non-mediation* conceptualizations, there is quite a high number of mixed results in correlational investigations (40%). This may, in part, explain the low percentage of significant results.

In general, the trend however is clear. Studies approaching presence using the *illusion of non-mediation* produce least significant evidence for all directions of the emotion-presence

relationship. Interpretation of these results depends on how one would view these different conceptualizations. If you believe the conceptualizations to refer to conceptually distinct types of presence, then presence according to the *illusion of non-mediation* simply does not correlate well with emotion. In other words, whether or not one is aware of the mediating technology, has no impact on, and is not impacted by, emotion experienced in the environment. This is in line with claims made by Wirth and colleagues, who believe the illusion of non-mediation is neither necessary, nor sufficient, for the experience of presence (Wirth et al., 2007).

However, if you believe the different conceptualizations of presence to approach the same concept, then the *illusion of non-mediation* may not be sufficient to describe the phenomenon of presence. That would explain why studies conceptualizing presence according to a *combination* of place illusion and illusion of non-mediation find strongest results, as perhaps both place illusion and illusion of non-mediation are vital components of the presence experience (Lombard & Ditton, 1997; Slater et al., 1994).

It is important to note that how an author *says* they conceptualize presence may actually be less important than the actual methods and measures they apply. The presence measures adopted make certain assumptions that likely have most impact on the results acquired. However, one may argue that how an individual conceptualizes a concept, may subconsciously influence different stages of the research process, from setting up the study, to interpretation of the results. The current section attempted to investigate whether different results are obtained, based on the conceptualizations adopted, but more detailed investigations should be conducted into whether the different research phases are actually influenced, and differ between the different theorists.

Results per emotion type

In addition to this, it was investigated whether the results across studies differed, depending on the emotions the studies targeted. By far, the most commonly measured emotion was anxiety, followed by fear, sadness, relaxation, joy, and arousal/valence. It is not surprising that anxiety (followed by fear) was commonly investigated in the current literature set. Because of the nature of the current investigation, it was natural to include investigations into VRET (Virtual Reality Exposure Therapy), which tend to be especially interested in investigating emotions such as anxiety and fear.

Studies measuring *sadness*, *relaxation* and *joy* find strongest evidence, for all directions of the emotion-presence relationship they investigate (100%). For studies including *arousal/valence*, there is also considerable evidence for all directions they measure, be it less strong (>67%). It should be noted that not all emotion investigations explore all causal investigations. For studies assessing *anxiety* and *fear*, results are more varied, and will be elaborated upon below.

Regarding *fear*, evidence is considerable for a correlation between presence and fear (100%), for a causal effect of fear on presence (100%), and for a causal effect of presence on fear (67%). Evidence is at chance level for a circular relationship, however (50%). In the case of *fear* investigations, the mixed results are represented by a single study, in which the findings were due to an aforementioned effect of time (Peperkorn et al., 2015), highlighting the possibility of a (temporally or otherwise) complex emotion-presence dynamic.

Regarding *anxiety*, evidence is clearly present for the causal effect of anxiety on presence, presence on anxiety, and a circular relationship (>75%), however clearly lower than for all other emotion investigations. Additionally, evidence for a correlation is at around chance level (55%). Interestingly, this is clearly not due to a large number of mixed results. Compared to studies focused on other emotions, those studies focusing on a correlation between presence

and anxiety show the lowest percentage of significant findings (55%), *and* the highest percentage of insignificant findings (25%). This is especially interesting, considering anxiety is the most common emotion among all investigations, hence one would expect these findings to be more robust.

This relatively low evidence for an emotion-presence correlation (as compared to causational investigations) is common throughout the data set, however this finding may imply that studies investigating *anxiety* may be partially responsible for this trend, and responsible for skewing the general results. It remains illogical that evidence for a correlation between emotion and presence is lower, when evidence for all causal investigations is quite strong. However, perhaps this finding illustrates that there are dynamics between presence and anxiety, that are different for other emotions. For instance, these dynamics may be influenced by the strength of the anxiety experienced. It has been proposed by Robillard and colleagues that, if the level of anxiety experienced is too high, this may actually be distracting and interfere with the experience (Robillard et al., 2003), and perhaps influence the way anxiety interacts with presence.

In general, the differences between the different emotions are not substantial. For all emotions involved, there is generally a similar support for emotion-presence dynamics. While there were noticeable results for studies investigating anxiety, it is currently not the case that specific emotional attributes can be identified that clearly interact with presence in a different manner. Thus, the notion that presence only correlates with the arousal dimension of emotion, and hence only with emotions of an arousing nature (Freeman et al., 2005; Meehan et al., 2002), does not appear to be visible in the current data trends, and is not supported by the current investigation. The results of the current investigation are more in line with those acquired by

Ravaja and colleagues, in which a relationship between presence and emotion was also found on the dimension of *valence* (Ravaja, Salminen, et al., 2004)

Results per presence measurement

Next, it might be relevant to investigate how the results differed depending on the presence measurement used, as presence measurements tend to make implicit assumptions about the concept of presence. In the case of this SLR, all presence measures happened to be subjective self-report questionnaires, of which the most common ones were ITC-SOPI, IPQ, PQ, and SUS (as was previously stated in the section *General information*).

Comparing results, it appears that when studies use ITC-SOPI as a presence measure, they tend to find strongest and most consistent evidence for each direction of the relationship between presence and emotion (correlation, effect of emotion on presence, presence on emotion, and the circular relationship). Studies using SUS are in agreement, and find strong evidence for a correlation between presence and emotion (80%), however conduct no further causal investigations. Studies using IPQ and PQ find most varying results, and will be elaborated upon below.

Studies using IPQ as a presence measure tend to find strong evidence for a correlation between presence and emotion, for a causal effect of emotion on presence, and for a causal effect of presence on emotion (>70%). They tend, however, to not find evidence for a circular relationship (0%). It is important to note, that there was only 1 study in this category which investigated the circularity, and that study came up with mixed results. These mixed results were because the nature of the relationship between presence and emotion changed over-time (Peperkorn et al., 2015).

Studies using PQ tend to find most varied and insignificant results of all measures. Specifically, studies using PQ find significant evidence for a causal effect of presence on emotion

(100%), and for a circular relationship (100%), however not for a correlation (50%), nor for a causal effect of emotion on presence (33%). In both these cases, there are no mixed results to explain the findings.

Thus, when assuming presence as portrayed by the ITC-SOPI, SUS, and IPQ (i.e., using *physical presence*, *engagement*, *ecological validity*, *negative effects*, *dominance of VR*, and *presence as a real physical place*), then generally support for all directions of the emotion-presence relationship is found (Lessiter et al., 2001; Schubert et al., 2001; Schwind et al., 2019). For an exact explanation of each of the factors adopted by the presence questionnaires, see the section of *Presence measures,* provided in the literature review. However, when you assume presence can be represented by PQ, i.e., using *control factors*, *sensory factors*, *distraction factors*, and *realism factors* (Witmer & Singer, 1998), then results regarding the presence-emotion relationship are more varied.

The main difference between PQ on one side, and ITC-SOPI, SUS and IPQ on the other, appears to be the inclusion of *control factors* and *distraction factors*. One could reason about the use of such factors as a measure of presence. *Control factors,* as defined by the PQ measure, is *the degree of control an individual has in the VE.* It may be related to either the notion of *situated affordances* by the ecological view of presence (Flach & Holden, 1998; Schuemie & Van der Mast, 1999; Zahorik & Jenison, 1998), or to the notion of *effective interactions* by the embodiment framework of presence (Haans & IJsselsteijn, 2012)*,* in the sense that all these factors include successful interactions with, and manipulations of, the environment. Both the ecological view, and the embodiment framework, do not believe emotion and presence are necessarily correlated, nor do they believe emotion to have a causal effect on presence. Hence, it is not surprising that a measure approaching presence using a similar frame of mind, also does not find considerable evidence for a correlation, nor a causal effect of emotion on presence.

One might argue that perhaps the ecological view of presence, or the embodiment framework, might be targeting a somewhat different concept or viewpoint of presence.

Results per emotion measurement.

With regard to emotions, the types of measurements applied are more varied. In this case, there are both subjective self-report measures and objective physiological measures, and sometimes combinations of the two are included. It may be interesting to see which measures lead to the most consistent and significant results. First, a comparison will be made between the different self-report measures. Second, comparisons will be made between studies adopting only subjective measures, only objective measures, and those adopting a combination.

Comparison of subjective measures. The subjective self-report measures compared in this section are STAI, VAS, PANAS, and SUDS.

It appears studies applying VAS and PANAS as measures of emotion, find strongest and most stable evidence for all emotion-presence investigations, namely the correlation, causal effects and circular relationship (100% each). Studies using STAI and SUDS as emotion measures tend to produce more varied results.

Studies using STAI find a strong causal effect of emotion on presence, of presence on emotion, and a circular effect (>70%). They do not necessarily, however, find significant evidence for a correlation between emotion and presence (54%). In this case, the percentage of mixed studies is quite high, which might play a role.

Studies using SUDS tend to find significant (and strong) evidence for a correlation between presence and emotion (80%), for a causal effect of emotion on presence (67%), and for a causal effect of presence on emotion (100%). Whether or not they find significant evidence for a circular relationship between emotion and presence, tends to be at chance level (50%).

When comparing this finding to those established in the *emotion-specific results* section earlier, a trend becomes apparent. VAS and PANAS are measures applied to all sorts of emotions, whereas STAI and SUDS are measures of anxiety. Earlier, it became apparent that studies investigating *anxiety* produced variable results with regard to the emotion-presence relationship, specifically in terms of a correlation. Hence, it is expected that the section of anxiety-specific results, and those of measures of anxiety (STAI/SUDS), will show similar data trends. Whether these mixed results were due to the actual emotion of anxiety, or because of the questionnaires used to measure anxiety, remains the question.

Subjective versus objective measures. Next, it might be interesting to investigate how subjective versus objective measures of emotion are portrayed in data. Three categories were investigated, namely those who investigate emotion using only subjective measures, those using only objective measures, and those using a combination of both. The relevant physiological measures included HR measures (8 times), SC measures (3 times), and EMG measures (1 time).

Generally, most significant and stable results are found if studies make use of only *subjective measures*, in which case evidence is generally found for all directions of the emotion-presence relationship (>70%). If studies make use of *objective measures*, or a *combination* of both, then the only significant results found are for the causal effect of emotion on presence (100% and 67% respectively). It is interesting to note that, in the case that only objective measures are used, the lack of significant results cannot be explained by mixed results. In the case of *combination* studies, mixed results play a role, however (0-50%). This is to be expected, because by including multiple measures, you include a possible source of mixed results.

When formulating the results acquired, it seems that presence only has the ability to correlate with, and influence, the phenomenological experience of emotion (or at least individual's self-reports thereof), and not the physiological experience of emotion. Furthermore,

this entails that in the current investigation, the phenomenological and the physiological aspects of emotion, and their dynamics with presence, do not coincide. This may mean that *subjective* and *objective* measures of emotion differ in their suitability and validity as an emotion measure. In fact, objective and subjective measures of emotion may actually measure two different concepts, rather than they are a reflection of the same phenomenon.

In line with all of these scenarios, it is important to reconsider the meaning of physiological measures. The body's physiological system is a reflection of activity of the autonomic nervous system (ANS) (Öhman et al., 2000). ANS activity is however not solely a reflection of the emotional experience, but also of other processes related to e.g., attention, effort, digestion, and homeostasis (Berntson et al., 2017). It is often unclear whether ANS activity can be interpreted as a reflection of emotion, or perhaps rather as a reflection of another process (Obrist et al., 1970; Stemmler, 2004). In the current data, it may actually be the case that subjective and objective measures of emotion do not coincide, because they do not reflect the same processes occurring in the specific instance.

To progress the interpretation of emotion measurement results, it could be interesting to briefly discuss the interaction between physiological signals and presence further. All physiological measures of emotion used in the studies, have in the past also been indicated to be suitable physiological measures of presence (Meehan et al., 2002; Ravaja, Laarni, et al., 2004; Wiederhold, 2003). Given the fact that the current data set generally did *not* find physiological signals to be correlated with the sense of presence, this reasoning is not supported. In other words, the current SLR results support the claim that physiological measures are not necessarily a valid measure of presence, and are rather a reflection of another phenomenon. This has been suggested by several authors in the past (Diemer et al., 2015; Ravaja, Salminen, et al., 2004; Salnäss, 1999; Wiederhold et al., 1998). However, one could still argue that physiological

measures may be used as an indicator of presence, given the fact that emotion and presence tend to correlate.

Furthermore, in light of this finding, James' theory of emotion is not supported. From the perspective of James' theory, the only way in which presence would be able to have a causal effect on, and correlate with, emotion, is if it is able to directly evoke physiological signals, which the current data does not support.

Conclusion

The goal of the current study was to investigate the current-day view of literature regarding the relationship between presence and emotion. This section will aim to provide a summary of all the findings, and provide a conclusion based on the acquired data.

In general, a majority of studies find that there is evidence for all directions of the emotion-presence relationship. Presence is likely able to facilitate emotion formation by making an environment seem real and relevant. Emotion is in turn likely able to facilitate presence formation through the generation of attention(al) arousal, or by meeting an individual's expectations of an environment. However, there are a few indications that this circular relationship may be more complex (temporally or otherwise), and in order to make any conclusions regarding the exact nature of the circular relationship, more experiments should be conducted, for instance into temporal dynamics.

There are, however, two sidenotes to make. First, this relationship between emotions and presence appears to be quite similar for different types of emotions, regardless of their valence or arousal levels. An exception, however, may be anxiety, and anxiety measures STAI and SUDS, for which the relationship differs somewhat compared to other emotions and emotion measures.

Second, it should be noted that in the current investigation the relationship exists especially for the phenomenological experience of emotion, and not necessarily the physiological experience of emotion. In other words, subjective and objective measures of emotion do not coincide with regard to their presence dynamics, and the reason for this is unsure. More research needs to be done to interpret the relationship between objective and physiological measures of emotion in the current context.

From the point of view of presence, the relationship between presence and emotion is especially robust for most measures (ITC-SOPI, IPQ, and SUS). Results are somewhat more scattered when using PQ, however, which may be because of the inclusion of *control factors* and *distraction factors.* The possibility is discussed that perhaps PQ, and by extension the *ecological view* and *embodiment framework* of presence, concern a different concept of presence, compared to other presence measures and presence frameworks.

Investigations were done regarding whether or not it mattered how an author defined presence. In general, studies defining presence according to the notion of *media presence,* as compared to *inner presence*, find strongest evidence for presence-emotion dynamics. Within the media presence group, evidence for a relationship between emotion and presence is strongest when presence is defined to constitute of both an *illusion of non-mediation* and *place illusion*. However, the note is made that how an author *says* presence is defined may not be as important as their actual study design and presence measurement adopted. In the future, it may be valuable to investigate whether or not there are differences between the two groups of theorists, in the presence measures they adopt and study designs they create.

Future directions

The conclusion above mentioned a number of possible different future directions. This section will focus on one of the future directions proposed, and construct a possible research

design that may be adopted. Specifically, it will focus on the reciprocal relationship between presence and emotions, and any temporal dynamics that may or may not occur.

Study design. An example of a possible research design looks as follows.

Research questions. *Does a manipulation of presence have a causal effect on emotion experienced? Does a manipulation of emotion have a causal effect on presence experienced? Do temporal dynamics moderate the causal interactive links between presence and emotion?*

Experimental design. The current investigation is of a quantitative nature. Specifically, it is a 2x3 between-groups design, with six experimental conditions. Experimental manipulations are *presence* (low sensory realism vs. high sensory realism) and *emotion* (control environment vs. neutral environment vs. emotional environment).

Participants are positioned in a VE, and instructed to move around the space and find the exit. This environment consists of a number of hallways with signs indicating the direction of the exit. The environment is the same for all manipulations.

The VE is either provided to participants through a 2D computer monitor (low sensory realism; low presence), or through VR using a head-mounted display (HMD; high sensory realism; high presence). This design choice was made, because previous research has consistently shown that an HMD is able to elicit higher degrees of presence than a 2D computer monitor (Baños et al., 2004; Roettl & Terlutter, 2018; Shu et al., 2019). Individuals in both conditions are instructed to navigate using a hand-held controller.

This environment is then either accompanied by no music (control environment), by music of a neutral nature (neutral environment) or by music of an anxiety-inducing nature (emotional environment). In recent years, a range of different studies have shown the ability of music to elicit affect in listeners (Gagnon & Peretz, 2003; Mitterschiffthaler et al., 2007; Witvliet & Vrana, 2007). It is expected that anxiety-inducing music, together with the task to find an exit

in an unknown (virtual) environment, may trigger a need for escape and a feeling of anxiety. The decision was made to include a control environment without music, to control for the fact that any addition of music in itself may already elicit some sort of emotional reaction.

Participants. Participants are collected using the participant database of the JF Schouten School at Eindhoven University. Participants in the age category of 18-65 years old are accepted, however individuals with a history of mental illnesses are excluded. The current thesis has shown that results acquired using individuals with a history of mental disorders are not necessarily generalizable, hence the decision was made not to focus on that population group.

Research measures. Presence is measured in two ways. First, a single-item measure of presence is taken verbally, at three different points in time during the VE experience: in the beginning phase, the halfway phase, and the end phase. This single item reads *To which extent do you feel presence in the virtual environment, as if you were really there* (Bouchard et al., 2004). The choice was made to include a single item in order to limit the time taken away from the VR experience, but still be able to track how presence changes over-time. Additionally, the use of a single item has been found to be both a reliable and valid measure of presence (Bouchard et al., 2004).

Second, a longer post-test presence questionnaire is used. For the current investigation, that is the ITC-SOPI (Lessiter et al., 2001). The current investigation has shown that the ITC-SOPI is one of the most used and best established measures of presence, and most related to consistent results. See the section *Presence measurements* for a detailed investigation of the ITC-SOPI measure.

Emotion is also measured in two ways. First, using the Subjective Unit of Discomfort Scale (SUDS) (Wolpe, 1990). SUDS is an established single-item measure, in which individuals are asked to rate their current anxiety level on a scale of 0 to 100. SUDS is taken verbally at three

points during the VE experience, similar to the single-item presence measure. Even though the current investigation has shown that SUDS leads to relatively varying results in emotion-presence research, it is still one of the most established single-item measures of emotion. Additionally, this way the anxiety-presence dynamic can be investigated in more detail.

Second, two longer post-experiment emotion questionnaires are used. First, STAI is taken, which is a 20-item measure of anxiety. Second, VAS is taken, which is a visually-guided measure of emotion that can be adapted to fit any study and emotion measurement. The decision was made to include STAI, because the most relevant emotion of the current investigation is *anxiety*, hence an anxiety measure seems relevant. It was also decided to include VAS, however, because the current investigation has shown that using VAS is related to most consistent results in emotion-presence research. Previously an argument has been made that studies focused on anxiety, and specifically using SUDS and STAI, lead to somewhat more variable results. Whether this is due to the emotion or due to the emotion measure is unsure. By including VAS, a measure not traditionally designed for anxiety, perhaps more insight can be acquired into the dynamics between presence and anxiety. See the section *Emotion measurements* for a detailed investigation of both SUDS, STAI, and VAS.

Statistical procedures. In the current set-up, results are processed in two different ways. First, in order to answer the question how manipulations of emotion and presence impact each other, an *ANOVA* is conducted. In essence, ANOVA is used to investigate whether the six different experimental conditions significantly differ from each other. In this ANOVA, the post-experiment emotion- and presence measures are relevant.

Second, in order to investigate if the dynamic between presence and emotion changes over-time, the SUDS and single-item measure of presence are relevant, and compared across

the three time points, in a within-individual manner. Statistical measures adopted are possibly a *repeated measure correlation* or a *cross correlation function* (CCF).

Limitations

Several limitations can be mentioned for the current thesis. First, based on the different available theories, certain assumptions were made, specifically regarding how presence may fit into existing emotion formation theories and vice vera. These assumptions were then carried over into the *Results* and *Discussion* section of the thesis, in order to interpret the findings. It is important to note that these assumptions were mostly based on the educated insight of the current author, and may be prone to bias and misinterpretations. It is possible that the original authors of the multiple different frameworks may have different thoughts on the interaction between presence and emotion within their theoretical frame.

Second, in order to search for articles, it was necessary to identify keyword sets. The keywords were formulated, based on the most relevant and commonly used terms, present in the title, abstract, and keyword sets, of the articles already available and relevant to the author. For the keyword set of emotion, this concerned a number of terms not only related to aspects of emotion (e.g., arousal and valence), but also to specific emotion types (e.g., fear and anxiety). This comes with two difficulties. For one, this entails that, across studies, emotions are measured inherently differently, perhaps complicating the comparison. In addition to this, there are many different types of emotions in existence, which highlights that the possibility that an area of studies may have been missed, because the *emotion* keyword set may not have been complete.

Third, due to the limited number of relevant studies, and the lacking body of evidence, it might be difficult to compare the results obtained in the SLR in a meaningful manner. Especially because the nature of some of the investigations is quite detailed, there are a number of

findings which are solely based on the results of a handful of studies (or even singular studies). This diminishes the robustness, and perhaps the meaning, of these findings.

Fourth, it is important to note that a Systematic Literature Review can be considered to have limited strength when it comes to drawing conclusions. For one, this is due to the lack of statistics inherent to the method. It is a method suitable to obtain a general overview of literature, and compare studies otherwise difficult to compare, but more statistical procedures must be executed before significant conclusions can be drawn. Furthermore, the SLR is less concerned with the detailed methodology of each individual study, and as such the meaningfulness of the results that may have been acquired.

Fifth, it is important to consider the event of publication bias. Significant research findings are more likely to get published, hence in the current evaluation there may be an overrepresentation of significant results, leading to a skewed view of the presence-emotion dynamic.

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Appendix A

Keyword syntax for each database used in the systematic literature review, and number of results acquired in the search

Database	Keyword syntax	Results
SCOPUS	TITLE-ABS-KEY(emotion* OR affect OR affective OR affection* OR mood OR arous* OR valence OR anxi* OR fear OR phobi* OR relax* OR joy*) AND TITLE("presence") AND TITLE-ABS-KEY(virtual OR media OR mediated OR medium OR computer-generated OR immser*) AND SUBJAREA(PSYC OR COMP) AND DOCTYPE(ar OR cp) AND LANGUAGE(english)	360
Web of Science	#1 : AB = (emotion* OR “affect” OR affective OR affection* OR mood OR arous* OR valence OR anxi* OR fear OR phobi* OR relax* OR joy*) #2 : AK = (emotion* OR “affect” OR affective OR affection* OR mood OR arous* OR valence OR anxi* OR fear OR phobi* OR relax* OR joy*) #3 : TI = (emotion* OR “affect” OR affective OR affection* OR mood OR arous* OR valence OR anxi* OR fear OR phobi* OR relax* OR joy*) #4 : #1 OR #2 OR #3	202

	#5 : TI = (“presence”) #6 : AB = (virtual OR media OR mediated OR medium OR computer-generated OR immser*) #7 : AK = (virtual OR media OR mediated OR medium OR computer-generated OR immser*) #8 : TI = (virtual OR media OR mediated OR medium OR computer-generated OR immser*) #9 : #6 OR #7 OR #8 #10: WC = (Psychology OR Communication OR Computer Science) #4 AND #5 AND #9 AND #10	
ACM Digital Library	*Title:("presence")* *AND AllField:((emotion* OR "affect" OR affective OR affection* OR mood OR arous* OR valence OR anxi* OR fear OR phobi* OR relax* OR joy*))* *AND AllField:((virtual OR media OR mediated OR medium OR computer-generated OR immers*))*	73
PsychARTICLES	noft((emotion* OR "affect" OR affective OR affection* OR mood OR arous* OR valence OR anxi* OR fear OR phobi* OR relax* OR joy*)) AND ti(("presence"))	5

AND noft((virtual OR media OR mediated OR medium OR computer-generated OR immser*))

Note. Asterisks were used to include variations of words. Emotion* can refer to: emotion, emotions, emotional. Affection* to: affection, affectionate. Arous* to: arousal, arousing. Anxi* to: anxiety, anxious. Phobi* to: phobia, phobias, phobic. Relax* to: relax, relaxing, relaxed. Joy* to: joy, joyous, joyful.

Appendix B

General information of studies included in the systematic literature review

Citation	Goal	N	Age	Gender	P group	Media
(Alsina-Jurnet & Gutiérrez-Maldonado, 2010)	Investigate the influence of user characteristics on presence	210	23 (18-45)	173 F (82%), 37 M (18%)	Test anxiety (68) vs. no test anxiety (142)	VR
(Alsina-Jurnet et al., 2011)	Investigate the relationship between presence and anxiety in VRET	210	23 (18-45)	173 F (82%), 37 M (18%)	Test anxiety (68) vs. no test anxiety (142)	VR
(Aymerich-Franch, 2010)	Assess the influence of body participation on presence and emotions	56	23 (18-44)	24 F (43%), 32 M (57%)		VR
(Baños et al., 2004)	Investigate the role of immersion and media content on presence, specifically affective valence	60	25 (18-49)	37 F (62%), 23 M (38%)		VR, 2D monitor, rear projected video wall
(Baños et al., 2008)	Investigate the influence of stereoscopy on presence and intensity of positive mood	40	24 (18-40)	27 F (76%), 13 M (24%)		VR
(Bouchard et al., 2008)	Investigate the direction of the anxiety-presence relationship	31	45 (27-86)	26 F (84%), 5 M (16%)	Snake phobia	VR

(Cadet & Chainay, 2020)	Investigate how episodic memory in VEs interacts with factor such as immersion and presence	108	21 (18-27)	54 F (50%), 54 M (50%)		VR, 2D monitor
(Carmen Juan & Pérez, 2009)	Compare the levels of presence and anxiety in acrophobic situations using CAVE and HMD	25	23	5 F (20%), 20 M (80%)		VR, CAVE
(Carmen Juan & Pérez, 2010)	Investigate the influence of AR and VR acrophobic scenarios on presence and anxiety	20	28	4 F (20%), 16 M (80%)		VR, AR
(Chirico & Gaggioli, 2019)	Investigate how emotions elicited in VR differ from real life	50	24	25 F (50%), 25 M (50%)		VR, RL
(Felnhofer et al., 2014)	Analysis of presence, anxiety and physiological measures	65	24	56 F (86%), 9 M (14%)	High anxiety (30) vs. low anxiety (35)	VR
(Felnhofer et al., 2019)	Investigate the link between social presence, physical presence, and emotional responses to phobogenic virtual social stimuli	24	23	17 F(71%), 7 M (29%)	SAD (12) vs. healthy (12)	VR
(Ferrer-Garcia & Gutierrez-Maldonado, 2011)	Investigate the influence of modulating variables, such as presence, on the level of subjective	71	20	71 F (100%), 0 M (0%)	Anorexia (49) and bulimia (22)	VR

	discomfort of eating disorder patients in VEs					
(Gorini et al., 2011)	Investigate the influence of immersion and narrative on presence in a VR scenario	84	21 (19-25)	42 F (50%), 42 M (50%)		VR
(Gromer et al., 2019)	Investigate the causal link between presence and fear	49	29	37 F (75%), 12 M (25%)		VR
(Krijn et al., 2004)	Investigate he effect of VRET (using a HMD and CAVE) on patients with acrophobia	30	51	12 F (40%), 18 M (60%)	Acrophobic (30)	VR, CAVE
(Ling et al., 2012)	Investigate effects of stereoscopy on presence, anxiety and cybersickness	88	28 (18-70)	35 F (40%), 53 M (60%)		VR
(Liu et al., 2019)	Investigate effects of layout types and spatial information display types on elder visitors' presence and spatial identification	32	69	?		VR
(Lull & Bushman, 2016)	Investigate whether immersive qualities of 3D gaming influence violent game-play outcomes	194	?	122 F (63%), 72 M (37%)		2D monitor, projector, 3D projector
(Makowski et al., 2017)	Investigate the link between episodic memory and presence	244	27	78 F (32%), 166 M (68%)		2D monitor, 3D monitor

(Malbos et al., 2013)	Investigate the ability of VEs to generate presence and induce anxiety/stress	18	44 (24-72)	11 F (61%), 7 M (29%)	Acrophobic (18)	VR
(Peperkorn et al., 2015)	Investigate the causal relationship between presence and fear in VRET	22	25 (19-38)	22 F (100%), 0 M (0%)	Acrophobic (22)	VR
(Price & Anderson, 2007)	Investigate the role of presence in VRET	36	39	31 F (85%), 5 M (15%)	Anxiety- or Panic Disorder (36)	VR
(Price et al., 2011)	Investigate the relationship between three theorized components of presence, fear and treatment response	41	?	24 F (58%), 17 M (42%)	Social phobia (41)	VR
(Ravaja et al., 2006)	Investigate whether the nature of an opponent influences spatial presence, emotional response, threat and challenge appraisals when playing video games	99	24 (19-34)	48 F (49%), 51 M(51%)		VR
(Regenbrecht et al., 1998)	Investigate the influence of technical and technological parameters on the sense of presence	37	27 (20-46)	14 F (38%), 23 M (62%)		VR

(Riva et al., 2007)	Analyze the use of VR as an affective medium	61	21 (19-25)	35 F (57%), 26 M (43%)	VR
(Robillard et al., 2003)	Investigate the effectivity of therapeutic virtual environments derived from computer games (TVEDG)	26	34 (18-60)	?	VR
(Rodríguez-Ardura & Meseguer-Artola, 2016)	Testing a model that places cognitive processes and emotion at the core of presence formation, and considers gender as a moderator	2574	?	1330 F (52%), 1244 M (48%)	VR
(Schuemie et al., 2005)	Investigate the effects of locomotion technique on presence, fear, avoidance, and simulator sickness	42	30 (18-62)	23 F (55%), 19 M (45%)	VR
(Van Gelder et al., 2018)	Comparison of written versus visualized guardianship scenarios, on sense of realism, presence, negative affect, perceived risk and choice to intervene	83	23	0 F (0%), 83 M (100%)	Written, audio-videotape
(Västfjäll, 2003)	Investigate how presence, emotional reactions and emotion recognition	45	26	14 F (31%), 31 M (69%)	Audiochannels

	vary as a function of number of audio channels				
(Villani et al., 2012)	Investigate whether presence can be experienced more in VR, compared to reality	20	24 (23-27)	10 F (50%), 10 M (50%)	VR
(Villani et al., 2007)	Evaluate the efficacy of VR as a support tool in the relaxation process	64	25 (21-28)	34 F (53%), 30 M (47%)	VR, 2D monitor, audio
(Villani & Riva, 2008)	Investigate the efficacy of a relaxing narrative through a VE	60	25 (21-28)	30 F (50%), 30 M (50%)	VR, 2D monitor
(Wallach et al., 2009)	Investigate the connection between attachment categories and presence in VRET	99	21 (18-30)	70 F (71%), 29 M (29%)	VR
(Weibel et al., 2011)	Investigate the roles of cognitive appraisal, (tele)presence, and emotion in the context of media usage	30	21	15 F (50%), 15 M (50%)	2D monitor

Note. All percentages are rounded to full numbers. N = Number of participants. The column *age* contains mean age, followed by age range between brackets. In the *gender* column, F = Female, M = Male. P group = Participant group. Media = Media types compared in the study.

Appendix C

Content-information, and results, of studies included in the systematic literature review

Citation	P term	P concept	P meas.	Emotion	E meas.	E+P	E -> P	P -> E	E <-> P
(Alsina-Jurnet & Gutiérrez-Maldonado, 2010)	Presence	Place illusion	IPQ	Anxiety	STAI, TAI	+	+		
(Alsina-Jurnet et al., 2011)	Presence	Place illusion	IPQ	Anxiety	STAI, TAI	+	+		
(Aymerich-Franch, 2010)	Presence	Place illusion	SUS	Arousal, valence	Pictorial tool of Self-Assessment Manikin (SAM)	+			
(Baños et al., 2004)	Presence	?	ITC-SOPI, RJPQ	Sadness	-	+	+		
(Baños et al., 2008)	Presence	Place illusion	ITC-SOPI, SUS	Sadness, joy, relaxation, anxiety	VAS, PANAS	+			
(Bouchard et al., 2008)	Presence	?	Single item, PQ	Anxiety	STAI	~	~		

(Cadet & Chainay, 2020)	Presence	Place illusion	ITC-SOPI	Arousal, valence	SAM	+	+
(Carmen Juan & Pérez, 2009)	Presence	Place illusion	SUS	Anxiety	Single item	+	
(Carmen Juan & Pérez, 2010)	Presence	Place illusion	SUS	Anxiety	Single item	-	
(Chirico & Gaggioli, 2019)	Presence	Illusion of non-mediation	ITC-SOPI	General affect (Anger, awe, amusement, disgust, fear, pride, sadness, joy)	PANAS and other	+	
(Felnhofer et al., 2014)	Presence	Illusion of non-mediation	IPQ	Anxiety	STAI, HR	~	
(Felnhofer et al., 2019)	Physical presence	Illusion of non-mediation	IPQ	Anxiety	STAI-S, HR	-	
(Ferrer-Garcia & Gutierrez-Maldonado, 2011)	Presence	Place illusion	PQ	Discomfort	VAS	+	

(Gorini et al., 2011)	Mediated presence	Place illusion	UCL-PQ, ITC-SOPI	Arousal	HR	+	+		
(Gromer et al., 2019)	Presence	Place illusion	MEC-SPQ	Fear	STAI, HR, SC	+	+	-	-
(Krijn et al., 2004)	Presence	Illusion of non-mediation	IPQ	Anxiety	STAI	-			
(Ling et al., 2012)	Spatial presence	Place illusion	SUS, IPQ	Anxiety	Personal Report of Confidence as a Speaker (PRCS), HR	+			
(Liu et al., 2019)	Presence	Place illusion	PQ	Pleasure, arousal and dominance	Pleasure, Arousal and Dominance questionnaire (PAD)	+		+	
(Lull & Bushman, 2016)	Presence	Virtual objects are experienced as actual objects (Lee, 2004).	Self-made, Self-Assessment Manikin (Schneider et al., 2004)	Anger	Hostility subscale of the Multiple Affect Adjective Check List	~		~	

(Makowski et al., 2017)	Presence	Place illusion	ITC-SOPI	Valence, intensity and frequency of emotions	Self-constructed	+	+	+	+
(Malbos et al., 2013)	Presence	Place illusion	PQ, ITQ	Anxiety	Subjective Unit of Discomfort Scale (SUDS), HR	-	-		
(Peperkorn et al., 2015)	Presence	Place illusion	Single item, Breaks in Presence (BIPs), IPQ	Fear	SUDS, HR, SC	+	+	+	~
(Price & Anderson, 2007)	Presence	Interpretation of an artificial environment as if it were real (Lee, 2004)	PQ	Anxiety	SUDS	+	+	+	+
(Price et al., 2011)	Presence	The level of connection one feels with an environment	IPQ	Fear	PRCS, SUDS	+			

(Ravaja et al., 2006)	Presence	Illusion of non-mediation	ITC-SOPI	Arousal, valence	HR, EMG	~			
(Regenbrecht et al., 1998)	Presence	Place illusion	Self-made	Anxiety	STAI	~		+	
(Riva et al., 2007)	Presence	Media presence perception	UCL-PQ, ITC-SOPI	Anxiety, relaxation	VAS, PANAS, STAI	+	+	+	+
(Robillard et al., 2003)	Presence	Place illusion	ITQ-F, PQ-F	Anxiety	FSS-II-F, STAI-Y-F	+	+	+	+
(Rodríguez-Ardura & Meseguer-Artola, 2016)	Presence	Place illusion	(Novak, Hoffman, and Yung, 2000)	Happiness, annoyance, content	(Novak, Hoffman, and Yung, 2000)	~	~		
(Schuemie et al., 2005)	Presence	?	IPQ	Fear	SUDS, Behavioural measure: Avoidance	+		+	
(Van Gelder et al., 2018)	Presence	Place illusion	IPQ	Negative affect	(Van Gelder & De Vries, 2010)	+			
(Västfjäll, 2003)	Presence	Place illusion	(Larsson, Västfjäll & Kleiner, 2001)	Positive moods (elated, happy, positive) and	VAS	+			

				negative moods (depressed, anxious, sad)				
(Villani et al., 2012)	Presence	Inner presence	ITC-SOPI	Anxiety	STAI-S, SC	~		~
(Villani et al., 2007)	Presence	Inner presence	ITC-SOPI	Relaxation, anxiety	STAI, VAS, PANAS	+	+	+
(Villani & Riva, 2008)	Presence	Media presence: Illusion of non-mediation, and thus place illusion	ITC-SOPI	Relaxation, anxiety	STAI, VAS, PANAS	+		+
(Wallach et al., 2009)	Presence	Place illusion	PQ	Anxiety	Experience in Close Relationships (ECR)	-		
(Weibel et al., 2011)	Presence	Media presence: Illusion of non-mediation, and	Presence Scale (Kim & Biocca, 1997)	Enjoyment	Single item, HR	+		

	thus place illusion

Note. P term = Presence term. P concept = Presence conceptualization. P measure = Presence measurement used. E measure = Emotion measurement used. E+P = Correlation between presence and emotion. E -> P = Causal effect of emotion on presence. P -> E = Causal effect of presence on emotion. E <-> P = Circular relationship between presence and emotion. + = Significant evidence for this investigation was found. - = Insignificant evidence was found. ~ = Mixed results were found.

Appendix D

Overview of the mixed results obtained in studies included in the systematic literature review

Ref. #	Citation	Mixed result
1	Bouchard, S., St-Jacques, J., Robillard, G., & Renaud, P. (2008). Anxiety increases the feeling of presence in virtual reality. *Presence: Teleoperators and Virtual Environments*, *17*(4), 376-391.	Presence was measured in two ways: using a brief single-item measure, and using the PQ (Presence Questionnaire). Results were only significant for the brief measure, not for the longer measure.
2	Felnhofer, A., Kothgassner, O. D., Hetterle, T., Beutl, L., Hlavacs, H., & Kryspin-Exner, I. (2014). Afraid to be there? Evaluating the relation between presence, self-reported anxiety, and heart rate in a virtual public speaking task. *Cyberpsychology, Behavior, and Social Networking*, *17*(5), 310-316.	A correlation between presence and emotion was only found for specific dimensions of the IPQ presence questionnaire, namely for *sense of being there* and *realism*, but not *spatial presence* and *involvement*.
3	Lull, R. B., & Bushman, B. J. (2016). Immersed in violence: Presence mediates the effect of 3D violent video gameplay on angry feelings. *Psychology of Popular Media Culture*, *5*(2), 133.	There was an effect of experimental condition. A causal effect of *presence* on *anger* only existed in the condition in which a *violent* video game was played, not in the condition with a neutral video game.
4	Peperkorn, H. M., Diemer, J., & Mühlberger, A. (2015). Temporal dynamics in the relation between presence and fear in virtual	There was an effect of *time.* At early stages of the experiment, there was a causal effect of presence on

	reality. *Computers in Human Behavior*, *48*, 542-547.	fear. In later stages, this turned into a reciprocal dependency.
5	Ravaja, N., Saari, T., Turpeinen, M., Laarni, J., Salminen, M., & Kivikangas, M. (2006). Spatial presence and emotions during video game playing: Does it matter with whom you play?. *Presence: Teleoperators and virtual environments*, *15*(4), 381-392.	Presence is assumed to consist of *spatial presence* and *engagement* dimensions. Emotion was measured using HR and EMG. Specifically, it was *only* the *engagement* dimension of presence, that correlated with *only* the EMG measure.
6	Regenbrecht, H. T., Schubert, T. W., & Friedmann, F. (1998). Measuring the sense of presence and its relations to fear of heights in virtual environments. *International Journal of Human-Computer Interaction*, *10*(3), 233-249.	A simple correlational analysis showed an insignificant correlation between presence and emotion. A regression analysis, however, showed that presence significantly predicts emotion.
7	Rodríguez-Ardura, I., & Meseguer-Artola, A. (2016). Presence in personalised e-learning–the impact of cognitive and emotional factors and the moderating role of gender. *Behaviour & Information Technology*, *35*(11), 1008-1018.	There was an effect of gender. The correlation between presence and emotion, and the causal effect of emotion on presence, was only significant for females, and not males.
8	Villani, D., Repetto, C., Cipresso, P., & Riva, G. (2012). May I experience more presence in doing the same thing in virtual reality than in reality? An answer from a simulated job interview. *Interacting with Computers*, *24*(4), 265-272.	There was an effect of experimental condition. The correlation between presence and anxiety, and the causal effect of presence on anxiety, were only significant in the VR condition, and not the real-life condition.

Note. Ref # = Reference number. The reference number is used in the current thesis to refer to specific mixed results in this table.