Physiological assessment of User eXprience supported by Immersive Environments: First input from a literature review

Mariela Martinez, Giovanny Arbelaez Garces, Laurent Dupont, Anaëlle Hily, Mauricio Camargo, Christel Jacob, Jérôme Dinet

Physiological assessment of User eXprience supported by Immersive Environments: First input from a literature review

Mariela Martinez[1], Giovanny Arbelaez[1], Laurent Dupont[1], Anaëlle Hily[1,2,3], Mauricio Camargo[1], Christel Jacob[2,4], Jérôme Dinet[2]

[1] Université de Lorraine, ERPI, EA 3767, F-54000 Nancy, France
[2] Université de Lorraine, 2LPN, EA 7489, F-54000 Nancy France
[3] TEA (Tech Ergo Appliquées), F-54500 Vandœuvre-lès-Nancy, France
[4] Centre Hospitalier Régional Universitaire, CMRR, F-54511 Vandœuvre-lès-Nancy, France

Corresponding author: Giovanny Arbelaez, arbelaez5@univ-lorraine.fr
Keywords: Immersive environments – physiological devices – virtual reality – literature review

Abstract

Immersive virtual environments can support the co-design process during the early innovation stages. For these technologies to be used as a support tool researchers and designers need to better understand users' behaviors and experiences in these environments. While most of the existing literature proposes to assess immersive experiences using self-reported assessments such as questionnaires, some alternatives propose the use of physiological data. In this sense, biometric and physiological measures can be useful indicators to study human behavior and performance in immersive virtual environments in order to highlight what physiological data monitoring can bring to the understanding of user experience. Based on an analysis of 1850 papers retrieved from the main bibliographical databases, our paper is aiming to propose a systematic review of the scientific literature interested in the use of biometric evaluation of human behavior interaction in an immersive environment. Through this review, the different uses of the technologies and their perspectives as tools for the assessment of user experience in immersive environments are presented and discussed.

1. Introduction

Immersive or virtual environments can play an important role as tools to support the design and development of innovation projects. They have been used in multiple disciplines such as health (Vogt et al., 2015), entertainment (Parker et al., 2011), psychology (Wood et al., 2007), human behavior (Slater et al., 2006) and user experience (Silva et al., 2009). This shows a high potential for the technology as a tool in diverse applications. However, research on co-creation process involving user experience supported by immersive environment still needs more development (Dupont et al., 2018). Indeed, if the Immersive Collaborative Environment (ICE) tree describes the properties of collaborative experience and immersive experience (Dupont et al., 2017), we need to better understand how users interact with those technologies. Research methods in human-computer interaction have been developed to analyze user behavior and other human factors (Rubio-Tamayo et al., 2017). While most of the reported methods use self-assessment measures (i.e. questionnaires and survey), another part is based on the use of physiological measures (Rubio-Tamayo et al., 2017). However, the literature shows that these technologies have been used in many different ways to study immersive environment experiences and there is a plethora of methods and approaches. For this reason, it is important to make a synthesis on how biometric and physiological assessment have been applied to study immersive virtual environment experience for researchers to better use this approach. The aim of this study is therefore to propose a systematic literature review of Biometric assessment (or physiological assessment) in Immersive Environments (or virtual environment).

In this review, 1850 research articles published between 2000 and 2020 extracted from Scopus database were analyzed using a co-occurrence approach conducted with VOSviewer software. Next, from those articles 153

significant references in terms of biometric devices uses for assessment were selected and sorted. After this, 26 publications were analyzed to determine which parameters have been studied to evaluate virtual immersion. Finally, we summarized the biometric devices technologies found in the literature in three groups: Common Technologies, Original biometrics technologies and Non-typical biometric technologies.
The principal contribution of this work is to summarize relevant aspects of Biometric assessment in Immersive Environments: Which factors have been studied and which technologies have been employed.
The rest of this paper is structured as follows. In section 2, previous works on Immersive Virtual Environment (IVE) and a general background about the Biometrics devices used to measure IVE is developed. In section 3, Material and Methods are described. Sections 3 and 4 synthesizes the results and conclusions.

2. Previous works and general background

2.1. Immersive virtual environment experience assessment

While there are several tools (questionnaires) and models to study user experience on immersive environments (Tcha-Tokey et al., 2016), to our knowledge there are no other frameworks to analyze co-creation in virtual environments. For this reason, in this research we use the Immersive Collaborative Environments (ICE) tree structure developed by (Pallot et al., 2017). This model identifies the most relevant elements to assess immersive co-creation in virtual environments. These elements have been summarized in the Immersive Collaborative Environments (ICE) tree structure (cf. Figure 1).

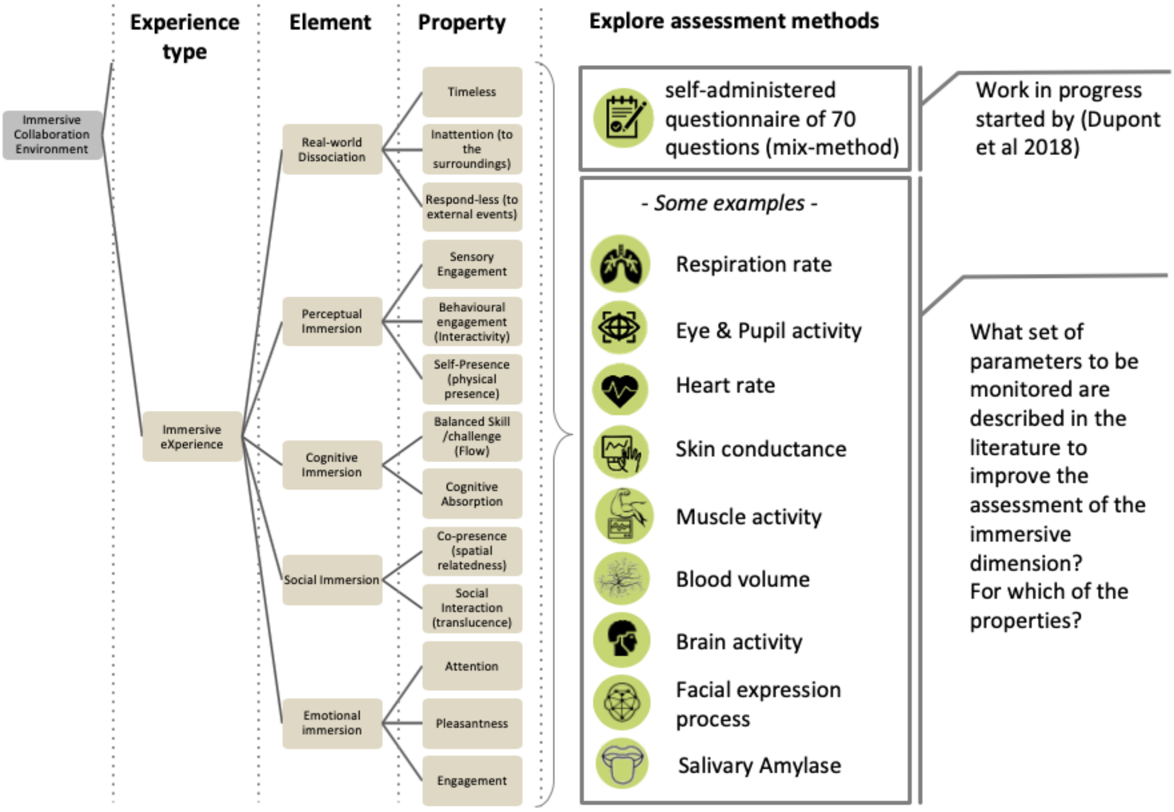

Figure 1. Exploration of assessment of immersive properties of the ICE structure based on (Dupont et al., 2017)

The ICE structure includes cognitive, social, perceptual and emotional facets. It is divided in two experience types: Immersive Experience and Collaborative Experience, both include their own elements and properties. The ICE tree has been applied by means of a questionnaire (self-reported measure) and survey instrument to assess the participants experience in immersive environments (Dupont et al., 2017). While the use of the ICE tree structure and the questionnaire instruments seems to give a complete picture of all the factors affecting the participants experience in immersive environments, self-assessment measurements present some limits because they rely on the ability and willingness of the respondent to accurately report their attitudes and prior behaviors (Lee et al., 2007). First experiments show the questionnaire is long and tedious for users. The participants are questioned after the experience. How could we collect their feedback at the time of the action, or even automate part of the collection? There seems to be some part of the answer in physiological responses as they can be collected when respondents are directly participating in the behavior and are difficult to control. For this reason, in this research we are interested to study how some of the ICE tree structure properties can be observed by means of biometrical devices as an alternative (or complement) to the existing instruments. For example, can respiration rate or eye pupil activity be used to assess one or several of the model properties. Figure 1 presents the tree structure and some of the possible devices to be explored. Furthermore, as the collaborative and immersive dimensions are complex and attached to different fields of research in this initial literature review, we will focus solely on the Immersive dimension (Figure 1). The collaborative dimension will be explored in further research.

2.2. Physiological devices for experience assessment

As seen from the ICE tree the immersive experience is affected by cognitive, social, perceptual and emotional facets. There has been extensive research in the fields of human behavior and decision-making processes. This research has shown that emotion plays a critical role guiding decision-making and behaviors in response to stimuli (Damasio, 1994), and also plays a crucial role regulating the interactions between humans and their environment (Dalgleish, & Power, 2013; Eimer, Holmes, & McGlone, 2003; Naqvi, Shiv, & Bechara, 2006). The processing of emotions is predominant in the limbic system (Shalev et al., 2017) located in the brain's medial temporal lobe. This system is responsible for processing emotional stimuli and regulating the expression of emotional responses to integrate them into complex brain functions. This process integrates the Central Nervous System (CNS) and the dynamics of the Autonomic Nervous System (ANS) (Marín-Morales et al., 2019). Because of this, emotion has a great impact on body responses. This is the working principle exploited by many of existing biometric devices that relies physiological responses to assess emotional and cognitive impact, states or types.

One of the impacts of emotion in body responses is expressed through facial expressions: helped by some neuronal groups called Central Pattern Generator (CPG), it initiates and controls facial muscle activities (López Mejía et al., 2009). Thus, some emotions can be recognized by the means of facial expressions (Winkielman et al., 2008). In terms of user experience this measure is related with social interaction and intention of participants, willingness to interact (Sacco & Hugenberg, 2012), empathy (Lundqvist & Öhman, 2005; Ruggiero et al., 2017), and as a confidence or trust indicator (Van IJzendoorn & Bakermans-Kranenburg, 2012; Weber & Brewer, 2006).

There are other patterns of physiological activation present in emotional states, such as: heart rate, respiratory rate, brain activity or galvanic activation of the skin (Hagemann et al., 2003). These can be used to measure the impact or relevance of a certain stimulus. However, it is difficult to identify with these biometric data alone to which of the six basic emotions the activation corresponds (Dawson et al., 2007). For this reason, it is often necessary to combine several of these measures (e.g. skin response and facial expressions).

Human emotional processing, interpretation of the facial expression process (Wicker et al., 2003), empathy (Jackson et al., 2005) and perception all involve the activity of the cerebral cortex and the CNS to automatically classify emotions and monitor the attentional meaning of emotions. Because of this, electroencephalogram (EEG) and FMRi are the most commonly used techniques to measure CNS responses (Valenza et al., 2016). In addition, EEG has been used to measure engagement (Castellar, E Voigt A., Jan N. & Marinazzo, D.& Looy, 2016; Cirett Galán & Beal, 2012; Shestyuk et al., 2019) and it can detect the perceived cognitive absorption (Conrad & Bliemel, 2016; Léger et al., 2014).

Changes on cardiovascular dynamics by specific emotional states (Marín-Morales et al., 2019) can be measured using electrocardiogram devices (ECG). Heart rate variability (HRV) has been used as an indicator of presence and pleasantness (Greenfeld et al., 2019; Jonathan et al., 2013; Meehan et al., 2002; Wood et al., 2007).

As a person becomes more or less stressed, the conductance of the skin increases or decreases proportionally (Slater et al., 2006). Galvanic Skin Response (GSR), is commonly used to establish the user's emotional states and it is used to measure sensory stimuli (e.g., pain, pressure, touch). In virtual reality settings it has been used as a presence indicator (Slater et al., 2006).

Finally, eye monitoring data, such as pupil dilation, fixations and saccadic eye movements, can determine pleasant or unpleasant emotions or reactions. Eye movement is measured by the mean of eye tracking devices.

The provision of information on the position of the eye is also related with a measure of joint-presence between two people (Špakov et al., 2019), attention (Wang et al., 2015), and it has been used as an indicator of context awareness (Bulling et al., 2008).
As seen from this brief literature background, some of the properties included in the ICE tree for immersive experience assessment have been assessed with the use of physiological measures. In particular presence attention, engagement and pleasantness. However, we need to better understand how authors have assessed those particular properties with physiological devices and if the other properties have been assessed. For this reason, we performed a systematic literature review on the use of physiological devices for the assessment of immersive environments experience.

3. Materials and methods

The objective of this study was to propose a systematic literature review of the use of biometric devices for assessment in Immersive Environment (or virtual environment) experiences. We performed a qualitative and systematic literature analysis using VOSviewer software (www.vosviewer.com). In this process, five filters were applied to narrow the number of publications found.

Table 1: Search parameters.

Field	Option
Keywords	TITLE-ABS-KEY ("immersive environment" OR "virtual environment" OR "immersive" OR "mixed reality" OR "virtual reality" OR "augmented reality") AND ("Biometric" OR "Physiological")
Search in	Title, abstract, keywords
Period explored	From 2000 to 2020
Type of documents	Articles and conference papers
Database	Scopus®

Filter 1. First, we searched in the Scopus database articles and conference papers from 2000 to 2020, using the title, abstract and keywords fields. The 20 years period was chosen because as analyzed from the (Dupont et al., 2018) research it was appeared that before 2000 there are few research works on the immersive experience assessment question. The search parameters are presented in Table 1, the search equation used the keywords: Immersive environment (or Virtual) and Biometrics (or Physiological).
With this first filter a total of 1850 publications were found.
Filter 2. The second step was to use the proximity operator "W/50" between the same keywords. This tip is provided by Scopus to make sure all terms appear in the same paragraph. Applying this filter 530 publications were found.
Filter 3. Using exclusion criteria of English publications and excluding duplicates, a total number of 513 publication result.
Filter 4. Then on this step, we read and analyzed the abstracts of the 513 selected articles, for a quantitative analysis. After the screening 153 publications were chosen as the most relevant, because there were several works unrelated to immersive environment from the previous filter. In addition, we excluded papers performing literature reviews, using languages different from English and we maintained application studies using biometrical devices in Virtual environments. Those 153 selected papers were carefully reviewed and classified to the category of biometric devices used (common technology, original technology and non-typical technology), classified by their study objectives and classified according to the properties of the ICE structure (cf. Appendix B).
Filter 5. This filter based on reading and analyzing the abstracts of those 153 selected articles, for a quantitative analysis, 26 publications were chosen. This filter consisted in the analysis of the topics to select which of those were focused exclusively in immersion study and not for other types of applications, we identified among them the parameters to be monitored used in the immersion research.

4. Findings

4.1. Data analysis through visualization

A total of 1850 studies from the first filter were analyzed with the VOSviewer software. Using co-occurrence links, a network of keywords was developed and mapped (cf. Figure 2). The circle represents the keywords and its diameter represents the frequency of occurrence. The distance between words means the relatedness, so, the closer two words are located the stronger their relatedness.

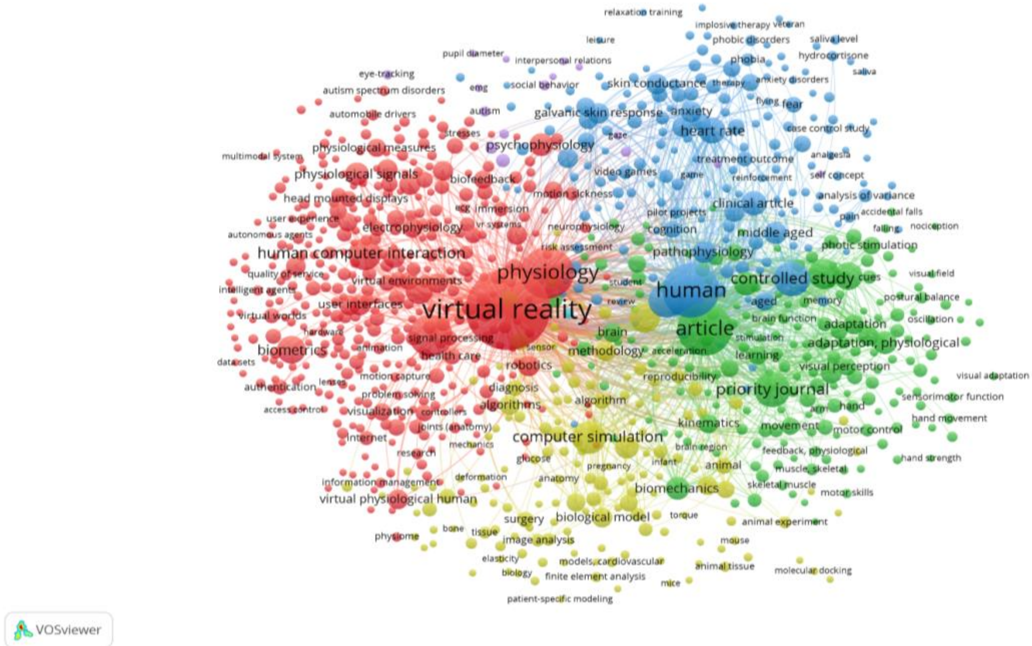

Figure 2. Network analysis of 1850 publications by VOSviewer software

In figure 2, a collection of keywords having strong relationship creates a cluster, each represented by a different color. A total of four main clusters were identified by VOSviewer. Table 2 details each cluster, color, main keywords and others related words. Form table 2 we observe that each cluster might be associated with a certain research trend. The first trend represents the use of virtual environments as a tool for simulation and as an interface for simulators. The second trend shows that there is a stream of research that deals with the use of physiological responses for the study of human computer interaction. The third trend is the use of some specific commonly used variables in these studies, as heart rate, emotion, anxiety. The fourth cluster links some of the aims of the studies that were found (e.g. memory, learning or adaptation studies).

This initial analysis allows us to identify what type of studies have been performed and which types of technologies have been commonly used.

Table 2. Network analysis of 1850 publication with VOSviewer software

Cluster	Color	Main Keywords	Other related words	Research Trend
1	Yellow	Computer interface, simulation, article	Computer simulation, algorithm adaptation, software	Computer interface, simulation and article as a tool of virtual environment studies
2	Red	Virtual Reality	Human computer interaction, physiology, physiological response, biometrics	Virtual reality and human computer interaction use physiology and physiological responses
3	Blue	Heart Rate, Emotion	Psychophysiology, anxiety, attention, questionnaires, stress, arousal, self-report	Variables as hear rate, emotion, anxiety and others are variables used in virtual reality environments
4	Green	Vision, Biomechanics, adaptation, human experiment	Movement, memory, learning, adaptation	Those keywords may reflect aims or objectives of the researches

4.2. Document analysis

Based on the Filter 4 the 153 selected publications were first categorized by the application domain and aim of study. Then we performed a detailed analysis on the different technologies that were used.

In an initial analysis we identified five main categories of the aim of the studies. Most of the studies intended to understand and Improve effectiveness of virtual environment (71), a second stream was concerned with Psychological purposes (51), then studies related to Simulation to measure performance (13), then studies related to Health (12) in general and studies related to Education and training purposes (6).

4.2.1. Biometric devices used to measure Immersive Virtual Environments

On the analyzed papers biometric devices were used to measure the emotions and assess the experience of the participants in immersive virtual environments. We summarized them in three categories according to the frequency in which they have been found in the literature: common, original and non-typical technologies. Common technologies are devices that were found on at least 5 studies, original technologies are technologies that were developed for a specific purpose of the study, and non-typical technologies are technologies that were used by less than 5 studies. In particular, we observe that they correspond to existing devices or technologies but are rarely used in the context of immersion studies. Among the studies 82% of the papers used common technologies, 14% used non-typical technologies and 4% developed their own original technologies.

4.2.2.Common Technologies

In common technologies, the most used technology or physiological response to measure virtual environment was heat rate measure (89 studies), followed by skin conductance (67 studies). Other common technologies are less frequently used as respiration rate (20 studies), EEG (30 studies), EMG (9), Blood Flow Velocity (9) and Salivary Aplha Amylase or Cortisol (10). The eye tracking technology that is common in user experience studies was less common on the immersive experience studies found (8 studies).

In the case of Heart rate measures with ECG it has been commonly used with EEG to assess emotional responses and the sense of presence (Marín-Morales et al., 2019; Vogt et al., 2015). In addition, GSR and Respiration Rate measurement devices were used to evaluate emotional (Silva et al., 2009) states and as a measure of stress levels (Hägni et al., 2008; Tinga et al., 2019; Wood et al., 2007). GSR have been used in cognitive rehabilitation as an indicator of presence (Lo Priore et al., 2003; Slater et al., 2006).

Jackson et al. (2015) developed the Evolutive Virtual Environment for Empathy Improvement (EEVEE). It is based on three main components: (1) different avatars capable of expressing feelings and emotions in various levels based on the Facial Action Coding System (FACS); (2) systems to measure the observer's physiological responses (heart and respiratory rate, skin conductance, eye and eye movements, facial expression); and (3) a multimodal interface that links the behavior of the avatar with the neurophysiological response of the observer. EEVEE consists of a series of devices that will allow real-time measurement of the behavioral and physiological responses of the participants, using biometric devices such as: Face Reader (Nolduls) as an emotional face recognition tool to create avatars. In addition, they used measures of heart activity, respiration rate, and skin conductance, as well as eye-tracking and pupillometry.

In the case of eye movements they have been used as a predictor of emotional states and to assess the effects in virtual reality context (Cebeci et al., 2019). Other authors, have used eye tracking as a tool to improve the collaborative immersion experience. Murray et al., (2009) studied how the gaze is of paramount for subjects to correctly identify what a person is looking at in an immersive virtual environment. For this, they tested the differences observed when a subject tried to distinguish which objects in a scene looked at the avatar in the environment. As a result, they find that Eye-gaze has proven to be a key resource for collaborative interaction. In addition, eye-trackers were commonly used as attention, visual search and visual memory indicators in Immersive Experience (Kit et al., 2014).

4.2.3. Original Biometrics Technologies

In the case of original technologies different types were found. GNeuroPathy, Deep Long Short-Term memory (LSTM) and Multimodal Biofeedback System. GNeuroPhaty was a technology developed to measure electrodermal response in virtual reality (Quaresma et al., 2019). LSTM was developed to record state postural signal (Hofmann et al., 2018). Multimodal Biofeedback was designed to capture up to six biomedical signals: EMG, EEG, GSR, temperature, heart rate and respiratory rate simultaneously. Other developed technologies were found: Virtual Reality Medical Center (VRMC), Integrative system, Foveal Eye movements, eyeblink potentiation, Ear-Eye Pitch (E2P), PhysioVR, OpenViBe.

Quesnel & Riecke (2018) studied interactive virtual reality as a positive technology that can generate astonishment and how the scale of beauty / aesthetics, familiarity and personalization characteristics (self-selection of travel destinations) can induce astonishment. To measure the physiological response related to the incredible emotional experience, they created a "chicken-skin camera" that consisted of a webcam to capture changes in skin texture. The person uses the device on his non-dominant arm and was designed to accommodate virtual reality manual controllers. The video of the camera was analyzed to determine the presence of goosebumps on the skin.

It is still complex to measure facial expressions in the virtual environment, because the use of HMDs covers the person face. However, Burn (2017) has developed a device called MASK, a base in foam sensitive to neurons that comprises a ring of sensors that can be inserted in the front plate of any VR headset. This biometric technology allows to detect the user's facial expressions and translate the emotion expressed through virtual avatars in real time.

4.2.4.Non typical biometric technologies in VR

In this category we identified existing technologies that are uncommon to be found in virtual or immersive environment studies. However, they are common in other fields of study such as medicine, biology, neuroscience or others. These were used in these virtual studies mainly because the variable studies were very specific, so they integrated different tools from other areas of knowledge, such as neuroscience (Alcañiz et al., 2018). We found the use of oxygen consumption (VO 2) was used in 3 studies, accelerometers (2 papers), mean ventilation responses (1 paper), body forces (1 paper), transcranial Doppler (1 paper).

Blood flow and oxygen consumption was used in anxiety studies while salivary measures to cortisol (Stress) studies. Among the studies that used a non-typical measures (Yu et al., 2018) created a health application that uses VR and biometric measurements. The objective was to examine the influence of forest and urban environments of virtual reality on health. To measure the impact of the VR environment three biometric measures were used: heart rate frequency, salivary α amylase activity, to quantify stress levels. It was measured using a salivary amylase monitor DM-3.1. Additionally, participants Blood Pressure was used to detect the right position of participants' arm or movement it was measured by blood pressure monitor (HEM-1000).

Other studies focused on comparing the immersive environment and the real environment based on other physiological responses. Yeom et al., (2019) focused their study on determining whether a thermal quality component and a component built in a built environment could generate some physiological problems, compared to the real-world environmental condition. For this, they used a biometric temperature sensor (STS-BTA).

4.3. Use of properties from the ICE structure

Based on the 153 publications from Scopus we classified the properties studied in each publication quantitatively in the ICE structure (cf. figure 3 and appendix B).

From the 153 publications, only 39 of these studies used at least one of the properties proposed by the ICE structure. Most of the properties from the ICE structure that were used by the studies are those related to emotional immersion facet, being Attention and Presence the most studied properties.

A final filter (Filter 5) was applied to select twenty-six studies that exclusively focused on immersion research. We found that 20 (77%) articles from the 26 used at least one of the properties proposed in the ICE tree structure. From the 26 analyzed studies 58% used only properties found in the ICE structure, 23% used some of the properties in the ICE structure but combined them with other properties, and 19% used only properties that are not included in the ICE structure. Among the other variables included in immersion studies researchers used anxiety (in 3 studies) and stress (2 studies). In terms of parameters to be monitored to assess the different properties that affects the immersive experience figure 3 synthesis the results related to the technologies and properties of the ICE model. Appendix B presents the technologies used for parameter monitoring in all the papers. As presented previously it is shown that heart rate, respiration rate and skin conductance measure are the most used technologies. The Self-presence property of is the one that has benefited from a higher development and use of parameter monitoring technologies followed by Attention property. It would be interesting to see further development of technologies to assess the other properties.

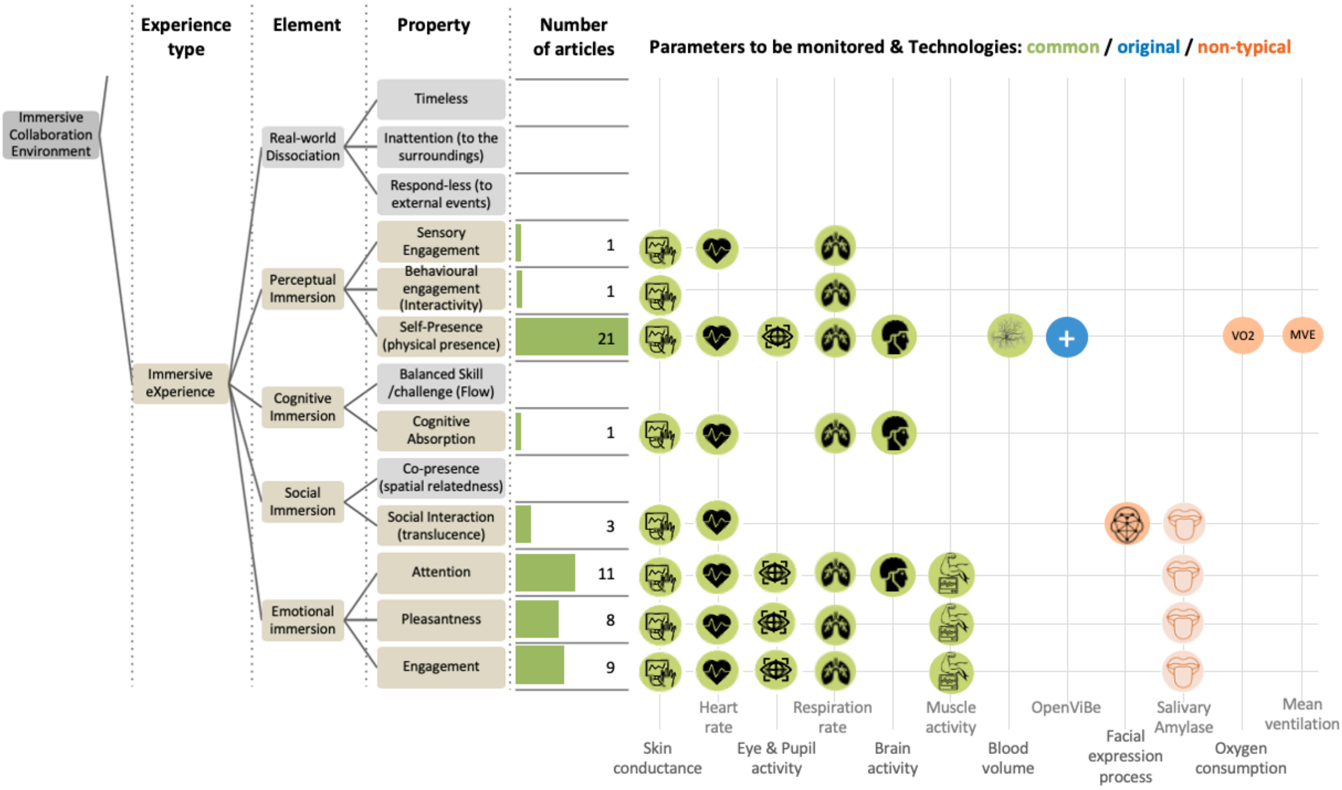

Figure 3. IX Properties and technologies found in the analyzed studies

5. Conclusion

For this study, a systematic literature review methodology with five filters was used to narrow down the number of potential articles collected from the Scopus database. An initial search presented 1850 publications for uses of biometric/physiological devices to measure virtual environment that were briefly explored. In an additional filter we narrowed them down to 153 to develop a qualitative analysis. This literature review contributes to mapping links and connection of the uses of biometric devices in Virtual Environments and some categories of their uses.

To measure immersive environment's experience many studies used biometric or physiological approaches. Their aim was mainly on improving the efficiency of the developed platforms.

Regarding technologies, heart rate and skin conductance were the most used physiological assessment devices used in virtual environments. However, in this review we presented some other non-typical and original technologies to evaluate virtual environments such as blood flow and salivary measures.

Our initial aim was to understand how the physiological technologies have been used for assessing properties and facets of the immersive dimension of ICE tree structure, in order to facilitate the use of the ICE tree model in assessing immersive experiences in complementarity of the already employed questionnaire and survey instruments. From the analyzed studies we observe that 8 of the properties included in the model have been evaluated by a biometrical approach. The most commonly assessed property is presence, as an indicator of immersion. Additionally, it was found that previous research in immersion studies have used Anxiety and Stress properties as an indicator of immersion. These two properties are not part of the ICE tree model, but this shows that further research should explore the inclusion or not of these properties for example to consider them in the Emotional aspect facet.

Additionally, we found that the availability of biometric tools coincides with the most studied properties or explained in another way, those that have been studied the least are the ones that have less biometric tools available according to what we saw in the review. This represents a great opportunity not only to study the variables proposed in the ICE but also to develop or propose physiological tools that will allow them to be studied.

This review is not without some limitations, it is only a partial view of the existing literature the presented annexes and list of papers are the base that need to be enriched by a deeper qualitative analysis on the uses of the physiological devices and their use constraints. To operationalize the uses of the devices to assess the different properties we need to consider the multifactorial dimension of the parameters monitored, the interpretation of the potential collected data will be a challenge.

6. Acknowledgments

This work was developed as part of a collaboration between ERPI, 2LPN under the project Inn-Cognitif laureate of the "interdisciplinarité 2019 call" of the Université de Lorraine. This study also benefits from N-Hum-Inno Labcom (ANR) led by ERPI and the company TEA.

7. References

Alcañiz, M., Parra, E., & Giglioli, I. A. C. (2018). Virtual reality as an emerging methodology for leadership assessment and training. *Frontiers in Psychology*, *9*(SEP), 1–7. https://doi.org/10.3389/fpsyg.2018.01658

Bulling, A., Roggen, D., & Tröster, G. (2008). It's in your eyes: Towards context-awareness and mobile HCI using wearable EOG goggles. *UbiComp 2008 - Proceedings of the 10th International Conference on Ubiquitous Computing*. https://doi.org/10.1145/1409635.1409647

Burn, J. (2017). *Neuro-sensitive foam shows your expression in VR before your face does*.

Castellar, E Voigt A., Jan N. & Marinazzo, D.& Looy, J. (2016). *Being in the zone: Using behavioral and EEG recordings for the indirect assessment of flow*.

Cebeci, B., Celikcan, U., & Capin, T. K. (2019). A comprehensive study of the affective and physiological responses induced by dynamic virtual reality environments. *Computer Animation and Virtual Worlds*. https://doi.org/10.1002/cav.1893

Cirett Galán, F., & Beal, C. R. (2012). EEG estimates of engagement and cognitive workload predict math problem solving outcomes. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-642-31454-4_5

Conrad, C., & Bliemel, M. (2016). Psychophysiological measures of cognitive absorption and cognitive load in E-learning applications. *2016 International Conference on Information Systems, ICIS 2016*.

Dalgleish, T., Power, M. (2013). (2013). *Handbook of Cognition and Emotion*.

Damasio, A. (1994). Descartes' error: Emotion, rationality and the human brain. In *New York: Putnam*.

Dawson, M. E., Schell, A. M., Filion, D. L., & Berntson, G. G. (2007). The Electrodermal System. In J. T. Cacioppo, L. G. Tassinary, & G. Berntson (Eds.), *Handbook of Psychophysiology* (pp. 157–181). Cambridge University Press. https://doi.org/10.1017/CBO9780511546396.007

Dupont, L., Pallot, M., Christmann, O., & Richir, S. (2018). A Universal Framework For Systemizing the Evaluation of Immersive And Collaborative Performance. *Proceedings of the Virtual Reality International Conference - Laval Virtual on - VRIC '18*, 1–10. https://doi.org/10.1145/3234253.3234306

Dupont, L., Pallot, M., Morel, L., Christmann, O., Boly, V., & Simon Richir, P. (2017). Exploring Mixed-methods Instruments for Performance Evaluation of Immersive Collaborative Environments. *International Journal of Virtual Reality (IJVR)*, *17*(02), 1–29.

Eimer, M., Holmes, A., & McGlone, F. (2003). The role of spatial attention in the processing of facial expression: An ERP study of rapid …. *Cognitive*.

Greenfeld, A., Lugmayr, A., & Lamont, W. (2019). Comparative reality: Measuring user experience and emotion in immersive virtual environments. *Proceedings - 2018 IEEE International Conference on Artificial Intelligence and Virtual Reality, AIVR 2018*. https://doi.org/10.1109/AIVR.2018.00048

Hagemann, D., Waldstein, S. R., & Thayer, J. F. (2003). Central and autonomic nervous system integration in emotion. *Brain and Cognition*. https://doi.org/10.1016/S0278-2626(03)00011-3

Hägni, K., Eng, K., Hepp-Reymond, M. C., Holper, L., Keisker, B., Siekierka, E., & Kiper, D. C. (2008). Observing virtual arms that you imagine are yours increases the galvanic skin response to an unexpected threat. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0003082

Hofmann, S. M., Klotzsche, F., Mariola, A., Nikulin, V. V., Villringer, A., & Gaebler, M. (2018). Decoding Subjective Emotional Arousal during a Naturalistic VR Experience from EEG Using LSTMs. *2018 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)*, 128–131. https://doi.org/10.1109/AIVR.2018.00026

Jackson, P. L., Meltzoff, A. N., & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *NeuroImage*. https://doi.org/10.1016/j.neuroimage.2004.09.006

Jackson, P. L., Michon, P. E., Geslin, E., Carignan, M., & Beaudoin, D. (2015). EEVEE: The Empathy-Enhancing Virtual Evolving Environment. *Frontiers in Human Neuroscience*. https://doi.org/10.3389/fnhum.2015.00112

Jonathan, K., James, H., James, G., Andrew, K., & Maree, A. (2013). Emotion Regulation and Heart Rate Variability: Effect of emotion reappraisal on subjective and cardiovascular responses to pleasant and unpleasant pictures. *Frontiers in Human Neuroscience*. https://doi.org/10.3389/conf.fnhum.2013.213.00044

Kit, D., Katz, L., Sullivan, B., Snyder, K., Ballard, D., & Hayhoe, M. (2014). Eye movements, visual search and scene memory, in an immersive virtual environment. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0094362

Lee, N., Broderick, A. J., & Chamberlain, L. (2007). What is 'neuromarketing'? A discussion and agenda for future research. *International Journal of Psychophysiology*, *63*(2), 199–204. https://doi.org/10.1016/j.ijpsycho.2006.03.007

Léger, P. M., Davis, F. D., Cronan, T. P., & Perret, J. (2014). Neurophysiological correlates of cognitive absorption in an enactive training context. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2014.02.011

Lo Priore, C., Castelnuovo, G., Liccione, D., & Liccione, D. (2003). Experience with V-Store: Considerations on presence in virtual environments for effective neuropsychological rehabilitation of executive functions. *Cyberpsychology and Behavior*. https://doi.org/10.1089/109493103322011579

López Mejía, D. I., Valdovinos de Yahya, A., Méndez-Díaz, M., & Mendoza-Fernández, V. (2009). El Sistema Límbico y las Emociones : Empatía en Humanos y Primates. *Psicología Iberoamericana*.

Lundqvist, D., & Öhman, A. (2005). Emotion regulates attention: The relation between facial configurations, facial emotion, and visual attention. *Visual Cognition*. https://doi.org/10.1080/13506280444000085

Marín-Morales, J., Higuera-Trujillo, J. L., Greco, A., Guixeres, J., Llinares, C., Gentili, C., Scilingo, E. P., Alcañiz, M., & Valenza, G. (2019). Real vs. immersive-virtual emotional experience: Analysis of psycho-physiological patterns in a free exploration of an art museum. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0223881

Meehan, M., Insko, B., Whitton, M., & Brooks, F. P. (2002). Physiological measures of presence in stressful virtual environments. *Proceedings of the 29th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH '02*. https://doi.org/10.1145/566570.566630

Murray, N., Roberts, D., Steed, A., Sharkey, P., Dickerson, P., Rae, J., & Wolff, R. (2009). Eye gaze in virtual environments: Evaluating the need and initial work on implementation. *Concurrency Computation Practice and Experience*. https://doi.org/10.1002/cpe.1396

Naqvi, N., Shiv, B., & Bechara, A. (2006). The role of emotion in decision making: A cognitive neuroscience perspective. *Current Directions in Psychological Science*. https://doi.org/10.1111/j.1467-8721.2006.00448.x

Pallot, M., Dupont, L., Christmann, O., Richir, S., Boly, V., & Morel, L. (2017). ICE Breaking: Disentangling Factors Affecting the Performance of Immersive Co-creation Environments. *Proceedings of the Virtual Reality International Conference - Laval Virtual 2017 on - VRIC '17*, 1–7. https://doi.org/10.1145/3110292.3110316

Parker, J. R., Baradoy, G., & Katz, L. (2011). Using virtual reality technology and biometric interfaces in obesity reduction. *Canadian Journal of Diabetes*. https://doi.org/10.1016/s1499-2671(11)52178-1

Quaresma, C., Gomes, M., Cardoso, H., Ferreira, N., Vigário, R., Quintão, C., & Fonseca, M. (2019). Gneuropathy: Validation process at clinical environment. *BIODEVICES 2019 - 12th International Conference on Biomedical Electronics and Devices, Proceedings; Part of 12th International Joint Conference on Biomedical Engineering Systems and Technologies, BIOSTEC 2019*, 275–279.

Quesnel, D., & Riecke, B. E. (2018). Are you awed yet? How virtual reality gives us awe and goose bumps. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2018.02158

Rubio-Tamayo, J., Gertrudix Barrio, M., & García García, F. (2017). Immersive Environments and Virtual Reality: Systematic Review and Advances in Communication, Interaction and Simulation. *Multimodal Technologies and Interaction*, *1*(4), 21. https://doi.org/10.3390/mti1040021

Ruggiero, G., Frassinetti, F., Coello, Y., Rapuano, M., di Cola, A. S., & Iachini, T. (2017). The effect of facial expressions on peripersonal and interpersonal spaces. *Psychological Research*.

https://doi.org/10.1007/s00426-016-0806-x
Sacco, D. F., & Hugenberg, K. (2012). Cooperative and competitive motives enhance perceptual sensitivity to angry and happy facial expressions. *Motivation and Emotion*. https://doi.org/10.1007/s11031-011-9256-3
Shalev, A., Liberzon, I., & Marmar, C. (2017). Post-traumatic stress disorder. In *New England Journal of Medicine*. https://doi.org/10.1056/NEJMra1612499
Shestyuk, A. Y., Kasinathan, K., Karapoondinott, V., Knight, R. T., & Gurumoorthy, R. (2019). Individual EEG measures of attention, memory, and motivation predict population level TV viewership and Twitter engagement. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0214507
Silva, D. C., Vinhas, V., Reis, L. P., & Oliveira, E. (2009). Biometric emotion assessment and feedback in an immersive digital environment. *International Journal of Social Robotics*. https://doi.org/10.1007/s12369-009-0029-z
Slater, M., Guger, C., Edlinger, G., Leeb, R., Pfurtscheller, G., Antley, A., Garau, M., Brogni, A., & Friedman, D. (2006). Analysis of physiological responses to a social situation in an immersive virtual environment. *Presence: Teleoperators and Virtual Environments*. https://doi.org/10.1162/pres.15.5.553
Špakov1, O., Istance1, H., Siirtola1, H., Räihä1, K.-J., Sinkonen1, H.-M., & Hällfors, A. (2019). *Using eye tracking to assist teaching reading in schools*.
Tcha-Tokey, K., Christmann, O., Loup-Escande, E., & Richir, S. (2016). Proposition and Validation of a Questionnaire to Measure the User Experience in Immersive Virtual Environments. *International Journal of Virtual Reality*, *16*(1), 33–48. https://doi.org/10.20870/IJVR.2016.16.1.2880
Tinga, A. M., Nyklíček, I., Jansen, M. P., de Back, T. T., & Louwerse, M. M. (2019). Respiratory Biofeedback Does Not Facilitate Lowering Arousal in Meditation Through Virtual Reality. *Applied Psychophysiology Biofeedback*. https://doi.org/10.1007/s10484-018-9421-5
Valenza, G., Greco, A., Gentili, C., Lanata, A., Sebastiani, L., Menicucci, D., Gemignani, A., & Scilingo, E. P. (2016). Combining electroencephalographic activity and instantaneous heart rate for assessing brain-heart dynamics during visual emotional elicitation in healthy subjects. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. https://doi.org/10.1098/rsta.2015.0176
Van IJzendoorn, M. H., & Bakermans-Kranenburg, M. J. (2012). A sniff of trust: Meta-analysis of the effects of intranasal oxytocin administration on face recognition, trust to in-group, and trust to out-group. *Psychoneuroendocrinology*. https://doi.org/10.1016/j.psyneuen.2011.07.008
Vogt, T., Herpers, R., Askew, C. D., Scherfgen, D., Strüder, H. K., & Schneider, S. (2015). Effects of exercise in immersive virtual environments on cortical neural oscillations and mental state. *Neural Plasticity*. https://doi.org/10.1155/2015/523250
Wang, H., Crewther, S. G., & Yin, Z. Q. (2015). The role of eye movement driven attention in functional strabismic amblyopia. In *Journal of Ophthalmology*. https://doi.org/10.1155/2015/534719
Weber, N., & Brewer, N. (2006). Positive versus negative face recognition decisions: Confidence, accuracy, and response latency. *Applied Cognitive Psychology*. https://doi.org/10.1002/acp.1166
Wicker, B., Keysers, C., Plailly, J., Royet, J. P., Gallese, V., & Rizzolatti, G. (2003). Both of us disgusted in My insula: The common neural basis of seeing and feeling disgust. *Neuron*. https://doi.org/10.1016/S0896-6273(03)00679-2
Winkielman, P., Niedenthal, P. M., & Oberman, L. M. (2008). Embodied Perspective on Emotion-Cognition Interactions. In *Mirror Neuron Systems*. https://doi.org/10.1007/978-1-59745-479-7_11
Wood, D. P., Murphy, J., Center, K., McLay, R., Reeves, D., Pyne, J., Shilling, R., & Wiederhold, B. K. (2007). Combat-related post-traumatic stress disorder: A case report using virtual reality exposure therapy with physiological monitoring. *Cyberpsychology and Behavior*. https://doi.org/10.1089/cpb.2006.9951
Yeom, D., Choi, J. H., & Zhu, Y. (2019). Investigation of physiological differences between immersive virtual environment and indoor environment in a building. *Indoor and Built Environment*. https://doi.org/10.1177/1420326X17731945
Yu, C. P., Lee, H. Y., & Luo, X. Y. (2018). The effect of virtual reality forest and urban environments on physiological and psychological responses. *Urban Forestry and Urban Greening*. https://doi.org/10.1016/j.ufug.2018.08.013

Appendix A. List of papers from the literature review

Ref	Detail
1	Jang, D. P., Kim, I. Y., Nam, S. W., Wiederhold, B. K., Wiederhold, M. D., & Kim, S. I. (2002). An investigation of immersiveness in virtual reality exposure using physiological data. *Studies in Health Technology and Informatics*. https://doi.org/10.3233/978-1-60750-929-5-207

2	Meehan, M., Insko, B., Whitton, M., & Brooks, F. P. (2002). Physiological measures of presence in stressful virtual environments. *Proceedings of the 29th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH '02*. https://doi.org/10.1145/566570.566630
3	Wiederhold, B. K., Gao, K., Sulea, C., & Wiederhold, M. D. (2014). Virtual reality as a distraction technique in chronic pain patients. *Cyberpsychology, Behavior, and Social Networking*. https://doi.org/10.1089/cyber.2014.0207
4	Zimmons, P., & Panter, A. (2003). The influence of rendering quality on presence and task performance in a virtual environment. *Proceedings - IEEE Virtual Reality*. https://doi.org/10.1109/VR.2003.1191170
5	Meehan, M., Razzaque, S., Insko, B., Whitton, M., & Brooks, F. P. (2005). Review of four studies on the use of physiological reaction as a measure of presence in stressful virtual environments. *Applied Psychophysiology Biofeedback*. https://doi.org/10.1007/s10484-005-6381-3
6	Orman, E. K. (2004). Effect of virtual reality graded exposure on anxiety levels of performing musicians: A case study. In *Journal of Music Therapy*. https://doi.org/10.1093/jmt/41.1.70
7	Herbelin, B., Benzaki, P., Renault, O., Grillon, H., Thalmann, D., & Riquier, F. (2005). Using physiological measures for emotional assessment: A computer-aided tool for cognitive and behavioral therapy. *International Journal on Disability and Human Development*. https://doi.org/10.1515/IJDHD.2005.4.4.269
8	Garau, M., Slater, M., Pertaub, D. P., & Razzaque, S. (2005). The responses of people to virtual humans in an immersive virtual environment. *Presence: Teleoperators and Virtual Environments*. https://doi.org/10.1162/1054746053890242
9	Meehan, M., Razzaque, S., Whitton, M. C., & Brooks, F. P. (2003). Effect of latency on presence in stressful virtual environments. *Proceedings - IEEE Virtual Reality*. https://doi.org/10.1109/VR.2003.1191132
10	Simeonov, P. I., Hsiao, H., Dotson, B. W., & Ammons, D. E. (2005). Height effects in real and virtual environments. *Human Factors*. https://doi.org/10.1518/0018720054679506
11	Goo, J. J., Park, K. S., Lee, M., Park, J., Hahn, M., Ahn, H., & Picard, R. W. (2006). Effects of guided and unguided style learning on user attention in a virtual environment. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/11736639_151
12	Slater, M., Antley, A., Davison, A., Swapp, D., Guger, C., Barker, C., Pistrang, N., & Sanchez-Vives, M. V. (2006). A virtual reprise of the Stanley Milgram obedience experiments. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0000039
13	Slater, M., Guger, C., Edlinger, G., Leeb, R., Pfurtscheller, G., Antley, A., Garau, M., Brogni, A., & Friedman, D. (2006). Analysis of physiological responses to a social situation in an immersive virtual environment. *Presence: Teleoperators and Virtual Environments*. https://doi.org/10.1162/pres.15.5.553
14	Slater, M., Antley, A., Davison, A., Swapp, D., Guger, C., Barker, C., Pistrang, N., & Sanchez-Vives, M. V. (2006). A virtual reprise of the Stanley Milgram obedience experiments. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0000038
15	Macedonio, M. F., Parsons, T. D., Digiuseppe, R. A., Weiderhold, B. K., & Rizzo, A. A. (2007). Immersiveness and physiological arousal within panoramic video-based virtual reality. *Cyberpsychology and Behavior*. https://doi.org/10.1089/cpb.2007.9997
16	Dotsch, R., & Wigboldus, D. H. J. (2008). Virtual prejudice. *Journal of Experimental Social Psychology*. https://doi.org/10.1016/j.jesp.2008.03.003
17	Yamamoto S., Miyashita H., Miyata A., Hayashi M., O. K. (2008). *Basic experiment for switching difficulty in virtual environment*.
18	Alcañiz, M., Rey, B., Tembl, J., & Parkhutik, V. (2009). A neuroscience approach to virtual reality experience using transcranial Doppler monitoring. *Presence: Teleoperators and Virtual Environments*. https://doi.org/10.1162/pres.18.2.97
19	Jordan, J., & Slater, M. (2009). An analysis of eye scanpath entropy in a progressively forming virtual environment. *Presence: Teleoperators and Virtual Environments*. https://doi.org/10.1162/pres.18.3.185
20	Vinhas, V., Silva, D. C., Oliveira, E., & Reis, L. P. (2009). Dynamic multimedia environment based on realtime user emotion assessment: Biometric user data towards affective immersive environments. *ICEIS 2009 - 11th International Conference on Enterprise Information Systems, Proceedings*. https://doi.org/10.5220/0001984100420047
21	Repetto, C., Gorini, A., Algeri, D., Vigna, C., Gaggioli, A., & Riva, G. (2009). The use of biofeedback in clinical virtual reality: The intrepid project. *Annual Review of CyberTherapy and Telemedicine*. https://doi.org/10.3389/conf.neuro.14.2009.06.085
22	Gorini, A., Mosso, J. L., Mosso, D., Pineda, E., Ruíz, N. L., Ramíez, M., Morales, J. L., & Riva, G. (2009). Emotional response to virtual reality exposure across different cultures: The role of the attribution process. *Cyberpsychology and Behavior*. https://doi.org/10.1089/cpb.2009.0192
23	Lustigova, Z., Dufresne, A., & Courtemanche, F. (2010). New attitude to learning in virtual environments - mining physiological data for automated feedback. *IFIP Advances in Information and Communication Technology*. https://doi.org/10.1007/978-3-642-15231-3_34
24	Song, M., Gromala, D., Shaw, C., & Barnes, S. J. (2010). The interplays among technology and content, immersant and VE. *The Engineering Reality of Virtual Reality 2010*. https://doi.org/10.1117/12.839444
25	Ranky, R., Sivak, M., Lewis, J., Gade, V., Deutsch, J. E., & Mavroidis, C. (2010). VRACK - Virtual Reality Augmented Cycling Kit: Design and validation. *Proceedings - IEEE Virtual Reality*. https://doi.org/10.1109/VR.2010.5444798
26	Groenegress, C., Spanlang, B., & Slater, M. (2010). The physiological mirror-a system for unconscious control of a virtual environment through physiological activity. *Visual Computer*. https://doi.org/10.1007/s00371-010-0471-9
27	Valtchanov, D., & Ellard, C. (2010). Exploring the restorative properties of urban and nature settings using virtual reality. *Proceedings of the 7th International Conference on Design and Emotion*.
28	Antley, A., & Slater, M. (2011). The effect on lower spine muscle activation of walking on a narrow beam in virtual reality. *IEEE Transactions on Visualization and Computer Graphics*. https://doi.org/10.1109/TVCG.2010.26
29	Rey, B., Parkhutik, V., Tembl, J., & Alcañiz, M. (2011). Breaks in presence in virtual environments: An analysis of blood flow velocity responses. *Presence: Teleoperators and Virtual Environments*. https://doi.org/10.1162/PRES_a_00049
30	Johnson, M. J., Chahal, T., Stinchcombe, A., Mullen, N., Weaver, B., & Bédard, M. (2011). Physiological responses to simulated and on-road driving. *International Journal of Psychophysiology*. https://doi.org/10.1016/j.ijpsycho.2011.06.012
31	Malbos, E., Rapee, R. M., & Kavakli, M. (2011). Isolating the effect of virtual reality based exposure therapy for agoraphobia: A comparative trial. *Annual Review of CyberTherapy and Telemedicine*. https://doi.org/10.3233/978-1-60750-766-6-45
32	Tröger, C., Ewald, H., Glotzbach, E., Pauli, P., & Mühlberger, A. (2012). Does pre-exposure inhibit fear context

	conditioning? A Virtual Reality Study. *Journal of Neural Transmission*. https://doi.org/10.1007/s00702-011-0757-8
33	Yang, S. R., Shi-An Chen, Shu-Fang Tsai, & Lin, C. T. (2012). Transcutaneous electrical nerve stimulation system for improvement of flight orientation in a VR-based motion environment. *ISCAS 2012 - 2012 IEEE International Symposium on Circuits and Systems*. https://doi.org/10.1109/ISCAS.2012.6271686
34	Ogorevc, J., Čop, A., Geršak, G., & Drnovšek, J. (2012). Evaluation of the measuring system for recording driver reaction time in virtual environment. *20th IMEKO World Congress 2012*.
35	de Sá, A. A. R., & Soares, A. B. (2012). Interface computacional 3D para biofeedback multimodal em tempo real. *Revista Brasileira de Engenharia Biomedica*. https://doi.org/10.4322/rbeb.2012.036
36	Sharma, N., & Gedeon, T. (2013). Modeling stress recognition in typical virtual environments. *Proceedings of the 2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops, PervasiveHealth 2013*. https://doi.org/10.4108/icst.pervasivehealth.2013.252011
37	Ocasio-De Jesús, V., Kennedy, A., & Whittinghill, D. (2013). Impact of graphical fidelity on physiological responses in virtual environments. *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*. https://doi.org/10.1145/2503713.2503751
38	Guo, R., Samaraweera, G., & Quarles, J. (2013). The effects of VEs on mobility impaired users: Presence, gait, and physiological response. *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*. https://doi.org/10.1145/2503713.2503719
39	Gerritsen, C., De Man, J., & Van Der Meij, J. (2013). Physiological and subjective response to injustice: The effects of unjust evaluations on physiological responses and subjective experiences. *Proceedings - 2013 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology - Workshops, WI-IATW 2013*. https://doi.org/10.1109/WI-IAT.2013.178
40	Chittaro, L. (2014). Anxiety induction in virtual environments: An experimental comparison of three general techniques. *Interacting with Computers*. https://doi.org/10.1093/iwc/iwt049
41	Vázquez, J. L. M., Santander, A., Mosso, J. L., Gao, K., Wiederhold, B., & Wiederhold, M. D. (2013). Using cybertherapy to reduce postoperative anxiety in cardiac recovery intensive care units. *Journal of Anesthesia and Clinical Research*. https://doi.org/10.4172/2155-6148.1000363
42	Jangraw, D. C., & Sajda, P. (2013). Feature selection for gaze, pupillary, and EEG signals evoked in a 3D environment. *GazeIn 2013 - Proceedings of the 2013 ACM Workshop on Eye Gaze in Intelligent Human Machine Interaction: Gaze in Multimodal Interaction, Co-Located with ICMI 2013*. https://doi.org/10.1145/2535948.2535950
43	Patton, D. (2014). How real is good enough? Assessing realism of presence in simulations and its effects on decision making. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-319-07527-3_23
44	Omata, M., Kagoshima, S., & Suzuki, Y. (2014). A physiological evaluation of immersive experience of a view control method using eyelid EMG. *PhyCS 2014 - Proceedings of the International Conference on Physiological Computing Systems*. https://doi.org/10.5220/0004719102240231
45	Meng, F., & Zhang, W. (2014). Way-finding during a fire emergency: An experimental study in a virtual environment. *Ergonomics*. https://doi.org/10.1080/00140139.2014.904005
46	Veling, W., Brinkman, W. P., Dorrestijn, E., & Van Der Gaag, M. (2014). Virtual reality experiments linking social environment and psychosis: A pilot study. *Cyberpsychology, Behavior, and Social Networking*. https://doi.org/10.1089/cyber.2012.0497
47	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*. https://doi.org/10.1089/cyber.2013.0472
48	Wiederhold, B. K., Jang, D. P., Kim, S. I., & Wiederhold, M. D. (2002). Physiological monitoring as an objective tool in virtual reality therapy. *Cyberpsychology and Behavior*. https://doi.org/10.1089/109493102753685908
49	Chittaro, L., & Sioni, R. (2013). Exploring eye-blink startle response as a physiological measure for affective computing. *Proceedings - 2013 Humaine Association Conference on Affective Computing and Intelligent Interaction, ACII 2013*. https://doi.org/10.1109/ACII.2013.44
50	Vogt, T., Herpers, R., Askew, C. D., Scherfgen, D., Strüder, H. K., & Schneider, S. (2015). Effects of exercise in immersive virtual environments on cortical neural oscillations and mental state. *Neural Plasticity*. https://doi.org/10.1155/2015/523250
51	Winslow, B. D., Carroll, M. B., Martin, J. W., Surpris, G., & Chadderdon, G. L. (2015). Identification of resilient individuals and those at risk for performance deficits under stress. *Frontiers in Neuroscience*. https://doi.org/10.3389/fnins.2015.00328
52	Miranda, M. R., Costa, H., Oliveira, L., Bernardes, T., Aguiar, C., Miosso, C., Oliveira, A. B. S., Diniz, A. C. G. C., & Domingues, D. M. G. (2015). Development of simulation interfaces for evaluation task with the use of physiological data and virtual reality applied to a vehicle simulator. *The Engineering Reality of Virtual Reality 2015*. https://doi.org/10.1117/12.2083889
53	Tartarisco, G., Carbonaro, N., Tonacci, A., Bernava, G. M., Arnao, A., Crifaci, G., Cipresso, P., Riva, G., Gaggioli, A., De Rossi, D., Tognetti, A., & Pioggia, G. (2015). Neuro-fuzzy physiological computing to assess stress levels in virtual reality therapy. *Interacting with Computers*. https://doi.org/10.1093/iwc/iwv010
54	Owens, M. E., & Beidel, D. C. (2015). Can Virtual Reality Effectively Elicit Distress Associated with Social Anxiety Disorder? *Journal of Psychopathology and Behavioral Assessment*. https://doi.org/10.1007/s10862-014-9454-x
55	Soyka, F., Kokkinara, E., Leyrer, M., Buelthoff, H., Slater, M., & Mohler, B. (2015). Turbulent motions cannot shake VR. *2015 IEEE Virtual Reality Conference, VR 2015 - Proceedings*. https://doi.org/10.1109/VR.2015.7223321
56	Deniaud, C., Honnet, V., Jeanne, B., & Mestre, D. (2015). An investigation into physiological responses in driving simulators: An objective measurement of presence. *Proceedings of the 2015 Science and Information Conference, SAI 2015*. https://doi.org/10.1109/SAI.2015.7237225
57	Moghim, M., Stone, R., Rotshtein, P., & Cooke, N. (2015). Adaptive virtual environments: A physiological feedback HCI system concept. *2015 7th Computer Science and Electronic Engineering Conference, CEEC 2015 - Conference Proceedings*. https://doi.org/10.1109/CEEC.2015.7332711
58	Moro, A. D., Quintero, C., & Sarmiento, W. J. (2016). Narrative approach to assess fear of heights in virtual environments. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-319-50835-1_62

59	Zhou, Z., Mingshao, Z., Yizhe, C., Esche, S. K., & Chassapis, C. (2016). A virtual laboratory combined with biometric authentication and 3D reconstruction. *ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE)*. https://doi.org/10.1115/IMECE201666799
60	Patrão, B., Pedro, S., & Menezes, P. (2016). Human emotions and physiological signals: A classroom experiment. *International Journal of Online Engineering*. https://doi.org/10.3991/ijoe.v12i04.5098
61	Crescentini, C., Chittaro, L., Capurso, V., Sioni, R., & Fabbro, F. (2016). Psychological and physiological responses to stressful situations in immersive virtual reality: Differences between users who practice mindfulness meditation and controls. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2016.02.031
62	Callejas-Cuervo, M., Martínez-Tejada, L. A., & Botero-Fagua, J. A. (2017). Architecture of an emotion recognition and video games system to identify personality traits. *IFMBE Proceedings*. https://doi.org/10.1007/978-981-10-4086-3_11
63	Saeidi, S., Lowe, A., Johannsen, N., & Zhu, Y. (2017). Application of Immersive Virtual Environment (IVE) in Occupant Energy-Use Behavior Studies Using Physiological Responses. *Congress on Computing in Civil Engineering, Proceedings*. https://doi.org/10.1061/9780784480830.047
64	Park, S. J., Subramaniyam, M., Kim, S. E., Hong, S., Lee, J. H., & Jo, C. M. (2017). Older driver's physiological response under risky driving conditions— overtaking, unprotected left turn. *Advances in Intelligent Systems and Computing*. https://doi.org/10.1007/978-3-319-41627-4_11
65	Jeon S., Lee W.-H., ". (2014). *Presence measurements analysis based on EEG characteristics for the personalized time-based media*.
66	Eudave, L., & Valencia, M. (2017). Physiological response while driving in an immersive virtual environment. *2017 IEEE 14th International Conference on Wearable and Implantable Body Sensor Networks, BSN 2017*. https://doi.org/10.1109/BSN.2017.7936028
67	Rieder, R., Kristensen, C. H., & Pinho, M. S. (2017). Quality Assessment of Interaction Techniques in Immersive Virtual Environments Using Physiological Measures. *Proceedings - International Computer Software and Applications Conference*. https://doi.org/10.1109/COMPSAC.2017.196
68	Mirzaei, M. A., Chardonnet, J. R., & Merienne, F. (2018). Comparing real and virtual object manipulation by physiological signals analysis: A first study. *CHIRA 2018 - Proceedings of the 2nd International Conference on Computer-Human Interaction Research and Applications*. https://doi.org/10.5220/0006924401080115
69	Liszio, S., Graf, L., & Masuch, M. (2018). The relaxing effect of virtual nature: Immersive technology provides relief in acute stress situations. *Annual Review of CyberTherapy and Telemedicine*.
70	Mawalid, M. A., Khoirunnisa, A. Z., Purnomo, M. H., & Wibawa, A. D. (2018). Classification of EEG Signal for Detecting Cybersickness through Time Domain Feature Extraction using NaÏve Bayes. *2018 International Conference on Computer Engineering, Network and Intelligent Multimedia, CENIM 2018 - Proceeding*. https://doi.org/10.1109/CENIM.2018.8711320
71	Arndt, S., Perkis, A., & Voigt-Antons, J. N. (2018). Using virtual reality and head-mounted displays to increase performance in rowing workouts. *MMSports 2018 - Proceedings of the 1st International Workshop on Multimedia Content Analysis in Sports, Co-Located with MM 2018*. https://doi.org/10.1145/3265845.3265848
72	Dey, A., Piumsomboon, T., Lee, Y., & Billinghurst, M. (2017). Effects of sharing physiological states of players in collaborative virtual reality gameplay. *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/3025453.3026028
73	Wang, Y. G., Shen, Z. H., & Wu, X. C. (2018). Detection of patients with methamphetamine dependence with cue-elicited heart rate variability in a virtual social environment. *Psychiatry Research*. https://doi.org/10.1016/j.psychres.2018.10.009
74	Quaresma C., Gomes M., Cardoso H., Ferreira N., Vigário R., Quintão C., Fonseca M., ". (2019). *Gneuropathy: Validation process at clinical environment*.
75	Guna, J., Geršak, G., Humar, I., Song, J., Drnovšek, J., & Pogačnik, M. (2019). Influence of video content type on users' virtual reality sickness perception and physiological response. *Future Generation Computer Systems*. https://doi.org/10.1016/j.future.2018.08.049
76	Wang, X., Shi, Y., Zhang, B., & Chiang, Y. (2019). The influence of forest resting environments on stress using virtual reality. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph16183263
77	Ergan, S., Radwan, A., Zou, Z., Tseng, H. A., & Han, X. (2019). Quantifying Human Experience in Architectural Spaces with Integrated Virtual Reality and Body Sensor Networks. *Journal of Computing in Civil Engineering*. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000812
78	Cebeci, B., Celikcan, U., & Capin, T. K. (2019). A comprehensive study of the affective and physiological responses induced by dynamic virtual reality environments. *Computer Animation and Virtual Worlds*. https://doi.org/10.1002/cav.1893
79	Krogmeier, C., Mousas, C., & Whittinghill, D. (2019). Human–virtual character interaction: Toward understanding the influence of haptic feedback. *Computer Animation and Virtual Worlds*. https://doi.org/10.1002/cav.1883
80	Leite, S., Dias, M. S., Eloy, S., Freitas, J., Marques, S., Pedro, T., & Ourique, L. (2019). Physiological arousal quantifying perception of safe and unsafe virtual environments by older and younger adults. *Sensors (Switzerland)*. https://doi.org/10.3390/s19112447
81	Domes, G., & Zimmer, P. (2019). Acute stress enhances the sensitivity for facial emotions: a signal detection approach. *Stress*. https://doi.org/10.1080/10253890.2019.1593366
82	Zimmer, P., Wu, C. C., & Domes, G. (2019). Same same but different? Replicating the real surroundings in a virtual trier social stress test (TSST-VR) does not enhance presence or the psychophysiological stress response. *Physiology and Behavior*. https://doi.org/10.1016/j.physbeh.2019.112690
83	Oliveira, T., Noriega, P., Carvalhais, J., Rebelo, F., & Lameira, V. (2020). How Deep Is a Virtual Reality Experience? Virtual Environments, Emotions and Physiological Measures. *Advances in Intelligent Systems and Computing*. https://doi.org/10.1007/978-3-030-20227-9_43
84	Harris, S. R., Kemmerling, R. L., & North, M. M. (2002). Brief virtual reality therapy for public speaking anxiety. *Cyberpsychology and Behavior*. https://doi.org/10.1089/109493102321018187
85	Bullinger, A. H., Hemmeter, U. M., Stefani, O., Angehrn, I., Mueller-Spahn, F., Bekiaris, E., Wiederhold, B. K., Sulzenbacher, H., & Mager, R. (2005). Stimulation of cortisol during mental task performance in a provocative virtual environment. *Applied Psychophysiology Biofeedback*. https://doi.org/10.1007/s10484-005-6378-y
86	Arrouët, C., Congedo, M., Marvie, J. E., Lamarche, F., Lécuyer, A., & Arnaldi, B. (2005). Open-ViBE: A three dimensional

	platform for real-time neuroscience. *Journal of Neurotherapy*. https://doi.org/10.1300/J184v09n01_02
87	de Kort, Y. A. W., Meijnders, A. L., Sponselee, A. A. G., & IJsselsteijn, W. A. (2006). What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology*. https://doi.org/10.1016/j.jenvp.2006.09.001
88	Mühlberger A., Bülthoff H.H., Wiedemann G., Pauli P., ". (2007). *Virtual Reality for the Psychophysiological Assessment of Phobic Fear: Responses During Virtual Tunnel Driving*.
89	Kotlyar, M., Donahue, C., Thuras, P., Kushner, M. G., O'Gorman, N., Smith, E. A., & Adson, D. E. (2008). Physiological response to a speech stressor presented in a virtual reality environment. *Psychophysiology*. https://doi.org/10.1111/j.1469-8986.2008.00690.x
90	Arriaga, P., Esteves, F., Carneiro, P., & Monteiro, M. B. (2008). Are the effects of unreal violent video games pronounced when playing with a virtual reality system? *Aggressive Behavior*. https://doi.org/10.1002/ab.20272
91	Mühlberger, A., Sperber, M., Wieser, M. J., & Pauli, P. (2008). A virtual reality behavior avoidance test (VR-BAT) for the assessment of spider phobia. *Journal of Cyber Therapy and Rehabilitation*.
92	Silva, D. C., Vinhas, V., Reis, L. P., & Oliveira, E. (2009). Biometric emotion assessment and feedback in an immersive digital environment. *International Journal of Social Robotics*. https://doi.org/10.1007/s12369-009-0029-z
93	Munih, M., Riener, R., Colombo, G., Lünenburger, L., Müller, F., Slater, M., & Mihelj, M. (2009). MIMICS: Multimodal immersive motion rehabilitation of upper and lower extremities by exploiting biocooperation principles. *2009 IEEE International Conference on Rehabilitation Robotics, ICORR 2009*. https://doi.org/10.1109/ICORR.2009.5209544
94	Salva, A. M., Alban, A. J., Wiederhold, M. D., Wiederhold, B. K., & Kong, L. (2009). Physiologically driven rehabilitation using virtual reality. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-642-02812-0_94
95	Vinhas V., Silva D.C., Reis L.P., O. E. (2009). *Real-time biometric emotion assessment in an immersive environment*.
96	Zhang, L., Chi, Y. M., Edelstein, E., Schulze, J., Gramann, K., Velasquez, A., Cauwenberghs, G., & MacAgno, E. (2010). Wireless physiological monitoring and ocular tracking: 3D calibration in a fully-immersive virtual health care environment. *2010 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBC'10*. https://doi.org/10.1109/IEMBS.2010.5625969
97	Courtney, C. G., Dawson, M. E., Schell, A. M., Iyer, A., & Parsons, T. D. (2010). Better than the real thing: Eliciting fear with moving and static computer-generated stimuli. *International Journal of Psychophysiology*. https://doi.org/10.1016/j.ijpsycho.2010.06.028
98	Brouwer, A. M., Neerincx, M. A., Kallen, V., van der Leer, L., & Brinke, M. Ten. (2011). EEG alpha asymmetry, heart rate variability and cortisol in response to virtual reality induced stress. *Journal of Cyber Therapy and Rehabilitation*.
99	Jiang L., Wang R., Qian W., L. Y. (2013). *Low-cost VR system based on wireless accelerometer sensor*.
100	Bekele, Esubalew, Zheng, Z., Swanson, A., Crittendon, J., Warren, Z., & Sarkar, N. (2013). Understanding how adolescents with autism respond to facial expressions in virtual reality environments. *IEEE Transactions on Visualization and Computer Graphics*. https://doi.org/10.1109/TVCG.2013.42
101	Costanzo, M. E., Leaman, S., Jovanovic, T., Norrholm, S. D., Rizzo, A. A., Taylor, P., & Roy, M. J. (2014). Psychophysiological response to virtual reality and subthreshold posttraumatic stress disorder symptoms in recently deployed military. *Psychosomatic Medicine*. https://doi.org/10.1097/PSY.0000000000000109
102	Gaggioli, A., Cipresso, P., Serino, S., Pioggia, G., Tartarisco, G., Baldus, G., Corda, D., Ferro, M., Carbonaro, N., Tognetti, A., De Rossi, D., Giakoumis, D., Tzovaras, D., Riera, A., & Riva, G. (2014). A decision support system for real-time stress detection during virtual reality exposure. *Studies in Health Technology and Informatics*. https://doi.org/10.3233/978-1-61499-375-9-114
103	Argo, J., Ma, M., & Kayser, C. (2014). Immersive composition for sensory rehabilitation: 3D visualisation, Surround sound, and synthesised music to provoke catharsis and healing. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-319-11623-5_12
104	Hadley, W., Houck, C. D., Barker, D. H., Garcia, A. M., Spitalnick, J. S., Curtis, V., Roye, S., & Brown, L. K. (2014). Eliciting affect via immersive virtual reality: A tool for adolescent risk reduction. *Journal of Pediatric Psychology*. https://doi.org/10.1093/jpepsy/jst092
105	Jeon, S., & Park, W. (2017). Computing presence in nonfigurative virtual environment under color and motion stimulus. *FTC 2016 - Proceedings of Future Technologies Conference*. https://doi.org/10.1109/FTC.2016.7821740
106	Handouzi, W., Maaoui, C., Pruski, A., & Moussaoui, A. (2014). Objective model assessment for short-term anxiety recognition from blood volume pulse signal. *Biomedical Signal Processing and Control*. https://doi.org/10.1016/j.bspc.2014.07.008
107	Perrin, A. F., Xu, H., Kroupi, E., Řeřábek, M., & Ebrahimi, T. (2015). Multimodal dataset for assessment of quality of experience in immersive multimedia. *MM 2015 - Proceedings of the 2015 ACM Multimedia Conference*. https://doi.org/10.1145/2733373.2806387
108	Seinfeld, S., Bergstrom, I., Pomes, A., Arroyo-Palacios, J., Vico, F., Slater, M., & Sanchez-Vives, M. V. (2016). Influence of music on anxiety induced by fear of heights in virtual reality. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2015.01969
109	Diemer, J., Lohkamp, N., Mühlberger, A., & Zwanzger, P. (2016). Fear and physiological arousal during a virtual height challenge-effects in patients with acrophobia and healthy controls. *Journal of Anxiety Disorders*. https://doi.org/10.1016/j.janxdis.2015.10.007
110	Bronner, S., Pinsker, R., Naik, R., & Noah, J. A. (2016). Physiological and psychophysiological responses to an exer-game training protocol. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2015.03.003
111	Bian, Y., Yang, C., Gao, F., Li, H., Sun, X., Meng, X., & Wang, Y. (2016). A Physiological Evaluation Model for Flow-Experience in VR Games: Construction and Preliminary Test. *Proceedings - 2015 International Conference on Identification, Information, and Knowledge in the Internet of Things, IIKI 2015*. https://doi.org/10.1109/IIKI.2015.59
112	Bekele, E., Wade, J., Bian, D., Fan, J., Swanson, A., Warren, Z., & Sarkar, N. (2016). Multimodal adaptive social interaction in virtual environment (MASI-VR) for children with Autism spectrum disorders (ASD). *Proceedings - IEEE Virtual Reality*. https://doi.org/10.1109/VR.2016.7504695
113	Naimark L., B. P. (2016). *New biometrics Ear-Eye Pitch (E2P)*.
114	Meng, F., & Zhang, W. (2014). Way-finding during a fire emergency: An experimental study in a virtual environment.

	Ergonomics. https://doi.org/10.1080/00140139.2014.904006
115	Muñoz, J. E., Paulino, T., Vasanth, H., & Baras, K. (2016). PhysioVR: A novel mobile virtual reality framework for physiological computing. *2016 IEEE 18th International Conference on E-Health Networking, Applications and Services, Healthcom 2016*. https://doi.org/10.1109/HealthCom.2016.7749512
116	Fusaro, M., Tieri, G., & Aglioti, S. M. (2016). Seeing pain and pleasure on self and others: Behavioural and psychophysiological reactivity in immersive virtual reality. *Journal of Neurophysiology*. https://doi.org/10.1152/jn.00489.2016
117	Shiban, Y., Diemer, J., Brandl, S., Zack, R., Mühlberger, A., & Wüst, S. (2016). Trier Social Stress Test in vivo and in virtual reality: Dissociation of response domains. *International Journal of Psychophysiology*. https://doi.org/10.1016/j.ijpsycho.2016.10.008
118	van Gelder, J. L., Nee, C., Otte, M., Demetriou, A., van Sintemaartensdijk, I., & van Prooijen, J. W. (2017). Virtual Burglary: Exploring the Potential of Virtual Reality to Study Burglary in Action. *Journal of Research in Crime and Delinquency*. https://doi.org/10.1177/0022427816663997
119	Hubbard R., Sipolins A., Z. L. (2017). *Enhancing learning through virtual reality and neurofeedback: A first step*.
120	Breuninger, C., Sláma, D. M., Krämer, M., Schmitz, J., & Tuschen-Caffier, B. (2017). Psychophysiological Reactivity, Interoception and Emotion Regulation in Patients with Agoraphobia During Virtual Reality Anxiety Induction. *Cognitive Therapy and Research*. https://doi.org/10.1007/s10608-016-9814-9
121	Dey, A., Chen, H., Lindeman, R. W., & Billinghurst, M. (2018). Effects of manipulating physiological feedback in immersive virtual environments. *CHI PLAY 2018 - Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*. https://doi.org/10.1145/3242671.3242676
122	Nazemi M., Mobini M., Gromala D., Ko H.H., Carlson J. (2017). *Sonic therapy for anxiety management in clinical settings*.
123	McGregor, C., Bonnis, B., Stanfield, B., & Stanfield, M. (2017). Integrating Big Data analytics, virtual reality, and ARAIG to support resilience assessment and development in tactical training. *2017 IEEE 5th International Conference on Serious Games and Applications for Health, SeGAH 2017*. https://doi.org/10.1109/SeGAH.2017.7939256
124	Keighrey, C., Flynn, R., Murray, S., Brennan, S., & Murray, N. (2017). Comparing user QoE via physiological and interaction measurements of immersive AR and VR speech and language therapy applications. *Thematic Workshops 2017 - Proceedings of the Thematic Workshops of ACM Multimedia 2017, Co-Located with MM 2017*. https://doi.org/10.1145/3126686.3126747
125	Otsuka, S., Kurosaki, K., & Ogawa, M. (2017). Physiological measurements on a gaming virtual reality headset using photoplethysmography: A preliminary attempt at incorporating physiological measurement with gaming. *IEEE Region 10 Annual International Conference, Proceedings/TENCON*. https://doi.org/10.1109/TENCON.2017.8228049
126	Pallavicini, F., Ferrari, A., Zini, A., Garcea, G., Zanacchi, A., Barone, G., & Mantovani, F. (2018). What distinguishes a traditional gaming experience from one in virtual reality? An exploratory study. *Advances in Intelligent Systems and Computing*. https://doi.org/10.1007/978-3-319-60639-2_23
127	Suárez-Revelo J.X., Ruiz-Duque A., Toro J.P., Mejía-Bueno A.M., H.-V. A. . (2018). *Changes in Electrocardiographic Signals During Training in Laparoscopic Surgery Simulator: A Preliminary Report*.
128	Amores, J., Richer, R., Zhao, N., Maes, P., & Eskofier, B. M. (2018). Promoting relaxation using virtual reality, olfactory interfaces and wearable EEG. *2018 IEEE 15th International Conference on Wearable and Implantable Body Sensor Networks, BSN 2018*. https://doi.org/10.1109/BSN.2018.8329668
129	Sra, M., Xu, X., & Maes, P. (2018). Breathvr: Leveraging breathing as a directly controlled interface for virtual reality games. *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/3173574.3173914
130	Lohr, D., Berndt, S. H., & Komogortsev, O. (2018). An implementation of eye movement-driven biometrics in virtual reality. *Eye Tracking Research and Applications Symposium (ETRA)*. https://doi.org/10.1145/3204493.3208333
131	Peterson, S. M., Furuichi, E., & Ferris, D. P. (2018). Effects of virtual reality high heights exposure during beam-walking on physiological stress and cognitive loading. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0200306
132	Navarro, E., González, P., López-Jaquero, V., Montero, F., Molina, J. P., & Romero-Ayuso, D. (2018). Adaptive, Multisensorial, Physiological and Social: The Next Generation of Telerehabilitation Systems. *Frontiers in Neuroinformatics*. https://doi.org/10.3389/fninf.2018.00043
133	Brás, S., Soares, S. C., Cruz, T., Magalhães, T., Marques, B., Dantas, C., Fernandes, N., & Fernandes, J. M. (2018). The feasibility of an augment reality system to study the psychophysiological correlates of fear-related responses. *Brain and Behavior*. https://doi.org/10.1002/brb3.1084
134	Souza, V. C. De, Nedel, L., Kopper, R., Maclel, A., & Tagliaro, L. (2018). The effects of physiologically-adaptive virtual environment on user's sense of presence. *Proceedings - 2018 20th Symposium on Virtual and Augmented Reality, SVR 2018*. https://doi.org/10.1109/SVR.2018.00029
135	Peterson, S. M., Rios, E., & Ferris, D. P. (2018). Transient visual perturbations boost short-term balance learning in virtual reality by modulating electrocortical activity. *Journal of Neurophysiology*. https://doi.org/10.1152/jn.00292.2018
136	Tadayon, R., Crews, D., Gupta, C., & McDaniel, T. (2018). Differences in psychophysiological reactions to anxiety in individuals with varying trait anxiety scores. *HealthMedia 2018 - Proceedings of the 3rd International Workshop on Multimedia for Personal Health and Health Care, Co-Located with MM 2018*. https://doi.org/10.1145/3264996.3265005
137	Fralish, B., Nickels, M., & Garcia, J. (2018). Improved Physiology and Psychosocial Well-Being for Individuals with Physical Disabilities through Virtual Reality Immersion: a Case Study. *Journal of Developmental and Physical Disabilities*. https://doi.org/10.1007/s10882-018-9618-9
138	Fusaro, M., Tieri, G., & Aglioti, S. M. (2019). Influence of cognitive stance and physical perspective on subjective and autonomic reactivity to observed pain and pleasure: An immersive virtual reality study. *Consciousness and Cognition*. https://doi.org/10.1016/j.concog.2018.11.010
139	Marín-Morales, J., Higuera-Trujillo, J. L., Greco, A., Guixeres, J., Llinares, C., Gentili, C., Scilingo, E. P., Alcañiz, M., & Valenza, G. (2019). Real vs. immersive-virtual emotional experience: Analysis of psycho-physiological patterns in a free exploration of an art museum. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0223881
140	Michailidis, L., Lucas Barcias, J., Charles, F., He, X., & Balaguer-Ballester, E. (2019). Combining Personality and Physiology to Investigate the Flow Experience in Virtual Reality Games. *Communications in Computer and Information Science*. https://doi.org/10.1007/978-3-030-23528-4_7

141	Ciorap R., Andritoi D., Luca C., C. C. (2019). *Monitoring of cardiovascular parameters during rehabilitation after stroke event*.
142	Hofmann, S. M., Klotzsche, F., Mariola, A., Nikulin, V. V., Villringer, A., & Gaebler, M. (2019). Decoding subjective emotional arousal during a naturalistic VR experience from EEG using LSTMs. *Proceedings - 2018 IEEE International Conference on Artificial Intelligence and Virtual Reality, AIVR 2018*. https://doi.org/10.1109/AIVR.2018.00026
143	Chamilothori, K., Chinazzo, G., Rodrigues, J., Dan-Glauser, E. S., Wienold, J., & Andersen, M. (2019). Subjective and physiological responses to façade and sunlight pattern geometry in virtual reality. *Building and Environment*. https://doi.org/10.1016/j.buildenv.2019.01.009
144	Hertweck, S., Weber, D., Alwanni, H., Unruh, F., Fischbach, M., Latoschik, M. E., & Ball, T. (2019). Brain activity in virtual reality: Assessing signal quality of high-resolution EEG while using head-mounted displays. *26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019 - Proceedings*. https://doi.org/10.1109/VR.2019.8798369
145	Van Tetering, A. A. C., Wijsman, J. L. P., Truijens, S. E. M., Fransen, A. F., Beatrijs Van Der Hout-Van Der Jagt, M., & Guid Oei, S. (2019). Comparison of the psychological and physiological effects on students of a video-assisted or text introduction to a simulated task. *BMJ Simulation and Technology Enhanced Learning*. https://doi.org/10.1136/bmjstel-2017-000272
146	Hedblom, M., Gunnarsson, B., Schaefer, M., Knez, I., Thorsson, P., & Lundström, J. N. (2019). Sounds of nature in the city: No evidence of bird song improving stress recovery. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph16081390
147	Kritikos, J., Tzannetos, G., Zoitaki, C., Poulopoulou, S., & Koutsouris, P. D. (2019). Anxiety detection from Electrodermal Activity Sensor with movement interaction during Virtual Reality Simulation. *International IEEE/EMBS Conference on Neural Engineering, NER*. https://doi.org/10.1109/NER.2019.8717170
148	Šalkevicius, J., Damaševičius, R., Maskeliunas, R., & Laukienė, I. (2019). Anxiety level recognition for virtual reality therapy system using physiological signals. *Electronics (Switzerland)*. https://doi.org/10.3390/electronics8091039
149	Gao, T., Zhang, T., Zhu, L., Gao, Y., & Qiu, L. (2019). Exploring psychophysiological restoration and individual preference in the different environments based on virtual reality. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph16173102
150	Wang, Y., Chardonnet, J. R., & Merienne, F. (2019). VR sickness prediction for navigation in immersive virtual environments using a deep long short term memory model. *26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019 - Proceedings*. https://doi.org/10.1109/VR.2019.8798213
151	Martens, M. A. G., Antley, A., Freeman, D., Slater, M., Harrison, P. J., & Tunbridge, E. M. (2019). It feels real: physiological responses to a stressful virtual reality environment and its impact on working memory. *Journal of Psychopharmacology*. https://doi.org/10.1177/0269881119860156
152	Carrera Arias, F. J., Boucher, L., & Tartar, J. L. (2019). The Effects of Videogaming with a Brain-Computer Interface on Mood and Physiological Arousal. *Games for Health Journal*. https://doi.org/10.1089/g4h.2018.0133
153	Liu, Z., Zhao, Q., Sun, L., & Luo, Y. (2020). Application of Virtual Human Factor Verification to Fire Accidents at the Main Control Room in Nuclear Power Plant. *Lecture Notes in Electrical Engineering*. https://doi.org/10.1007/978-981-13-8779-1_100

Appendix B. ICE structure properties present in the literature papers.

SkC	HR	RR	EyeT	EEG	SkT	BFV	EMG	SAA	GNP	VR MC	INTS	FE	EBP	PVR	PP	OVIBE	BF	VO 2	MV E	FR	ACC	TCD
Skin conductance	Heart Rate	Respiration Rate	Eyetracker / ocular exploration	EEG	Skin temperature	blood flow velocity (BFV)	EMG	salivary alpha amylase or cortisol	GNeuro Pathy	VRMC	INTS	Foveal Eye	Eyeblink potentiatio	PhysioVR	Photoplethysmography	OpenViBe	Body forces	oxygen consumption	Mean ventilation responses	Facereader	Accelerometers	transcranial Doppler

	Immersive eXperience													Common Technology									Original Technologies											Non-Typical Technologies					
	RwD			PI			CI		SI		EI																											
Ref	RwDT	RwDI	RwDRI	PISE	PIBE	PISP	CIF	CICA	SICp	SISI	EIA	EIP	EIE	SkC	HR	RR	EyeT	EEG	SkT	BFV	EMG	SAA	GNP	VRMC	INTS	FE	EBPn	E2P	PVR	PP	OViBe	LSTM	MBS	BF	VO2	MVE	FR	ACC	TCD
1				x										x	x	x			x																				
2						x								x	x				x																				
3														x	x				x																				
4						x																																	
5														x	x																								
6						x									x																								
7											x	x	x	x	x	x			x		x																		
8										x				x	x																								
9						x								x	x				x																				
10														x	x																								
11											x						x																						
12						x								x	x																								
13															x																								
14										x				x																									
15								x						x	x	x			x																				
16														x																									
17																x		x																					
18						x																																	x
19						x								x			x																						
20											x	x	x	x		x			x																				
21														x	x				x																				
22															x																								
23											x			x	x	x	x																						
24						x								x	x	x																							
25															x																			x					
26														x	x	x																							
27														x	x																								
28																					x																		
29						x														x																			
30						x									x																				x	x			
31															x																								
32														x	x																								
33											x							x																					
34														x	x																								
35																																	x						
36																		x																					
37														x																									
38						x								x																									
39														x	x																								
40																					x																		
41															x					x																			
42																	x	x																					

43						x									x																								
44																			x	x	x																		
45														x	x																								
46														x																									
47						x									x																								
48															x																								
49															x																								
50						x									x			x																					
51														x	x							x																	
52														x		x																							
53														x		x																							
54														x	x	x																							
55														x	x																								
56						x								x	x																								
57											x	x	x	x	x			x																					
58															x																								
59																																					x		
60														x	x	x		x																				x	
61														x	x	x				x	x																		
62															x						x																		
63															x				x																x				
64														x	x			x																					
65						x												x																					
66						x								x	x																								
67					x									x	x																								
68																					x																		
69															x																								
70																																							
71																x																							
72															x																								
73															x																								
74																							x																
75														x	x	x			x																				
76																																x							
77																																							
78															x		x																						
79																																							
80														x	x																								
81											x	x	x									x																	
82															x							x																	
83											x	x	x		x																								
84															x																								
85																						x																	
86						x																									x								
87															x				x																				
88																																							
89															x					x																			
90															x																								
91														x	x																								
92											x	x	x	x	x	x																							
93														x	x																								
94														x	x			x						x															
95											x	x	x	x			x																						
96																		x							x														
97														x													x												
98															x			x				x																	
99																																						x	
100																	x																						
101														x	x	x																							
102														x	x																								
103														x	x			x																					
104															x	x																							

105						x												x																					
106																				x																			
107															x	x		x																					
108														x	x																								
109														x	x							x																	
110													x		x																								
111															x																								
112																		x																					
113																															x								
114																					x																		
115																													x										
116														x																									
117										x												x																	
118															x																								
119																		x																					
120															x																								
121															x																								
122														x	x																								
123														x	x																								
124														x	x																								
125																														x									
126															x																								
127															x			x																					
128																		x																					
129						x										x																							
130																										x													
131														x	x			x																					
132																		x																					
133															x																								
134						x								x	x																								
135																		x																					
136														x	x			x																					
137															x																								
138														x																									
139											x	x	x					x																					
140															x																								
141														x	x			x			x														x				
142																		x																					
143														x	x																								
144																		x																					
145														x	x							x																	
146														x																									
147														x																									
148														x					x	x																			
149																		x																					
150															x					x		x																	
151														x	x					x		x																	
152																		x																					
153														x			x	x																					