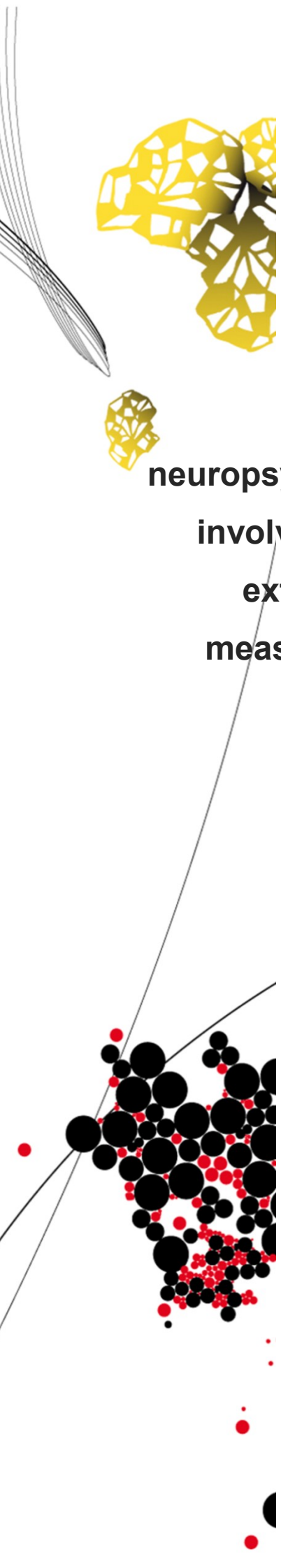

UNIVERSITY OF TWENTE.

Faculty of Behavioral, Management and Social Sciences

Investigating to what extent the neuropsychological three layer theory of presence, involving proto-presence, core presence and extended presence, is applicable to the measurement of presence in Virtual Reality: An Empirical Study.

MASTER THESIS

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I hope that you enjoy reading my thesis.

Judith Frissen
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Abstract

Interesting about Virtual Reality is that it can make people feel present in a situation which is at that moment not available or too unsafe in real-life. This feature called presence, is expected to be very promising for the field of education as it might promote natural, contextual, unlimited and safe learning with respect to all possible learning situations. However, there is still unclarity and dissension regarding the concept of presence in Virtual Reality as well as regarding how to firmly measure this concept. This study aims to find out whether presence in Virtual Reality can be considered as a basic neuropsychological phenomenon that involves three different layers of presence, which are proto-presence, core presence and extended presence. To date, no empirical study regarding this question was collected. By using data from forthy students at the University of Twente gathered through an observation list as well as through semi-structured interviews, a categorical principal component analysis was conducted in order to investigate whether the three neuropsychological layers of presence empirically could be identified. The results show some overlap between the three neuropsychological layers and hence no clear categorization into the three layers could empirically be identified. In addition, the results suggest that the reasons for the overlap between the layers lie in: a) an intertwining impact on all layers resulting from persons' general focus on environmental affordances, b) a shared dependence on conscious and interpretative effort by core- and extended presence, c) a shared dependence on form by proto-presence and core presence, and d) the absence of the need to survive in some virtual environments. Furthermore, the results suggest that the neuropsychological three layer theory of presence is not fully and directly applicable to the measurement of presence in VR due to some essential differences between real-life situations and virtual situations such as the social-cultural condition and the identification of imagination. The results of this study open up the road to the first empirical studies in this direction and can be used to direct further research in this angle.

Keywords: Virtual reality, measurement of presence, proto-presence, core presence, extended presence.

Table of content

1. Introduction

Virtual Reality (VR) can potentially be considered as a new and powerful learning tool. What is promising and distinctive about VR compared to other learning media is that only through VR it is possible to be physically placed as well as to posses control within a learning medium itself, which in turn leads to the unique experience of immersion and presence inside any possible learning situation (Wang, Petrina, & Feng, 2017). More specifically, Virtual Reality involves technology that promotes the creation of an interactive three dimensional digital environment in which an user is physically located and in which the user's behaviour has an instant and observable effect on the content of the environment (Fox, Arena, & Bailenson, 2009). To illustrate, through the capability of VR technology to track the movement of the user, it is for instance possible to determine when the user is standing in front of a virtual person, and to react on this user's behaviour by for instance letting the virtual person introduce oneself through shaking hands with the user and by telling him/her one's name. Simultaneously, the user's virtual surroundings will be rendered according to the user's movements, which in this case means that the user will see that he/she is nearing a virtual person and that the house he just left from is disappearing in the distance.

Virtual Reality Environments (VRE) can represent both real- and non-real situations (Mikropoulos & Natsis, 2011). It is worthy of addressing that the border between what is real and what is possible to create with the computer is rapidly becoming more vague (Regenbrecht, Franz, McGregor, Dixon & Hoermann, 2011). As a consequence, psychological behaviour, interactivity and perception in VR is likely to become more and more the same as in real-life, which is likely to enhance the feeling of really being there (Riva, Waterworth, & Waterworth, 2004). This feeling of really being there is what VR designers decisively try to promote (Riva et al., 2004). Here is where the terms immersion and presence are being coined. Immersion can be defined as the measurable and objective characteristics of a Virtual Reality environment (VRE) that have the potential to contribute to the experience of really being there through high technological capabilities (Slater, 2003). Presence can be considered as the psychological reaction of individuals to immersion, and involves the actual feeling of really being there (Slater, 2003).

The potential advantages of immersion and presence in VR for educational purposes are substantial. These benefits concern the possibility for students to learn through first-person experiences as well as through physical engagement with materials at all times and in safe and

contextual surroundings (Mantovani, Castelnuovo, Gaggioli, & Riva, 2003). Moreover, due to immersion and presence, students most likely do not have to conduct conceptualization in order to make sense of the world that is being simulated by the VR as this is happening automatically and naturally when feeling present, and thus does not require extra mental effort (Riva et al., 2004). In other words, learning with VR stimulates natural, unlimited and safe learning. On the whole, this is likely to promote construction of deeper knowledge (Mantovani et al., 2003), greater knowledge transferability to real-life situations (Johns, Nuñez, Daya, Sellars, Casanueva, & Blake, 2000) and increased motivation (Dalgarno & Lee, 2010).

In the light of the above mentioned potential advantages, nowadays, the interest in developing and using VR for educational purposes is rapidly increasing (Rose, Chang, & Cheng, 2018). As more time and money is being devoted to the development of virtual reality environments that try to empower education and training (Mantovani et al., 2003), it is more than ever important to know whether learning through immersive VR is actually effective. To date, there is still a lack of empirical evidence regarding its effectiveness. In order to be able to draw robust conclusions on the effectiveness of immersion and presence on learning outcomes, this empirical evidence is highly needed (Montavani et al., 2003). Important to realise here is that empirical evidence regarding the effect of presence on learning outcomes is assumed to be more valuable than empirical evidence regarding the effect of immersion on learning outcomes, as immersion can be seen as only influencing the unique feeling of being there whereas the psychological response called presence is what is actually and finally determining one's feeling of being there. However, before gathering this empirical evidence, one first needs to know how to firmly measure presence in order to gather valid evidence. So far, the presence literature contains limited congruence on how to define as well as on how to measure presence in VR (Haans, 2014).

With all in mind, it is interesting and relevant to conduct more studies on how to define and measure presence in VR in a valid way. Hence, this study aims to provide more insight on how to firmly conceptualise as well as on how to firmly measure presence in Virtual Reality through conducting a thorough analysis of the available literature on presence as well as by conducting an empirical investigation on the concept and measurement of presence in VR.

2. Theoretical framework

2.1. Immersion

Immersion can be seen from two points of view: the hardware view and the psychological view (Riva & Waterworth, 2013). In light of the hardware view, immersion can be considered as what the technology of a VRE objectively has to offer in order to potentially make the user feel presence, and thus involves the affective capabilities of the hardware (Slater & Wilbur, 1997). On the contrary, in consideration of the psychological view, immersion can be defined as a psychological condition that occurs when an user subjectively perceives oneself as enclosed and interactively engaged with an VR environment (Witmer & Singer, 1998). Remarkable is that the latter definition of immersion corresponds to what Slater and Wilbur (1997) label as presence. This means that looking at immersion from the psychological view of immersion makes it impossible to use the concepts immersion and presence as two different phenomena. Therefore, this study will use the hardware view as only then it is possible to make a distinction between immersion and presence. The importance of this distinction can be made clear as follows: when the technology encourages the feeling of presence through immersion in terms of high intensity of visuals and sounds, it still depends on the users' interpretative mechanisms, prior knowledge and experiences whether the user really feels presence. Noteworthy is that the majority of the latest research on presence also used the definition of immersion that conforms to the hardware view (Riva & Waterworth, 2013).

A virtual environment can have several technical qualities that promote immersion, such as high fidelity of representation and high interactivity. High fidelity of representation implies that the simulated virtual reality environment shares particular features with the real environment with the fewest shortcomings possible (Mahvash & Hayward, 2005). This can be achieved by for instance a smooth and consistent display regarding view alterations and object movements (Dalgarno & Lee, 2010). Also, user representation in form of an avatar can contribute to high fidelity of representation as it leads to a psychological depiction of yourself to another environment and the experience of a more realistic interaction with other objects. In addition, haptic technology can also enhance fidelity of representation as it enables learners to experience force and pressure in the VRE (Bowman, Kruijff, LaViola, & Poupyrev, 2004). In order to fully optimize immersion, the VRE should not only warrant high fidelity of representation but also high interactivity. High interactivity means that the VRE allows the

user to conduct embodied actions and to receive feedback on these embodied actions (Dalgarno & Lee, 2010). This can be achieved by for example providing the users with the opportunity to influence view, to control navigation, and to manipulate objects and the environment. (Dalgarno & Lee, 2010)

2.2. Presence

Also presence can be seen from two different points of view: the media perspective and the neuropsychological perspective. From a media point of view, presence can be defined as the subjective feeling of really being there in a virtual environment (Slater, 2003). In the light of this perspective, the concept of presence has been emerged only since the appearance of virtual reality, and hence involves a concept specifically applicable to VR technology (Riva, Waterworth, Waterworth, & Mantovani, 2011). However, some researchers state that presence is a basic psychological phenomenon which is not attributed to the involvement with virtual reality (Riva et al., 2011). They stress that presence concerns a daily process of understanding and surviving both the physical- and social world (Riva et al., 2011). This daily process of understanding and surviving the surrounding world involves a specific cognitive process that attempts to correctly connect intentions, perceptions and actions (Triberti & Riva, 2016). When somebody succeeds in this, one will have the impression of successfully putting intentions into actions, and, thereby, will experience agency and control (Riva et al., 2011). This impression of agency and control in our surrounding world is what the neuropsychological point of view sees as presence (Triberti & Riva, 2016).

As part of the neuropsychological view, Riva et al., 2004, propose the neuropsychological three layer theory of presence. According to this theory, presence can be split into three functionally different layers: proto-presence, core presence, and extended presence. In each of these layers, another process regarding surviving in the surrounding world is being enacted (Riva et al., 2004). With respect to the justification of the three layer theory of presence in specific, and the neuropsychological perspective on presence in general, it is stated that the feeling of really being there in a virtual environment is not different from the feeling of being there in our daily environment and own body (Riva et al., 2004). This would imply that the neuropsychological three layer theory of presence conforming real-life is applicable to presence in VR, and that understanding presence in virtual reality can only be

achieved by investigating it against the role of presence in our daily life. Therefore, this study will use the neuropsychological term of presence.

2.2.1 Proto-presence

2.2.1.1 The concept of proto-presence

The first neuropsychological layer of presence, proto-presence, can be interpreted as embodied presence (Riva et al., 2011). This layer of presence involves the instinctive perception of correctly distinguishing the physical self from the extrinsic world through perception-action coupling (Riva & Waterworth, 2013). The more a person is capable of properly connecting perceptions and movement, the more the person is able to physically distinguish oneself from the external world (Riva et al., 2011). For example, when a person activates movement in his or her arm and sees with one's eyes that his/her arm is going upwards, this person will connect this particular perception to this particular movement, and will thereby conclude that this thing, called an arm, belongs to his/her physical self rather than to the external world. This process of distinguishing one's physical self from the external world mostly happens unconsciously (Waterworth & Riva, 2014).

Successfully distinguishing one's physical self from the external world through perception-action coupling goes hand in hand with the construction of a body schema in which a person maps one's physical state as well as one's physical abilities (Riva & Waterworth, 2013). The construction of such body schema is highly valuable for experiencing proto-presence. The construction of a body schema namely enables the person to for instance determine the result of a certain movement (Riva & Montavani, 2012), to use the body as reference (Biocca, 1997), to make successful judgments regarding size and distance (Alshaer, Regenbrecht, & O'hare, 2017), and to conduct proper eye-hand coordination (Biocca, 1997). Additionally, updating one's body schema in a continuous and automatic fashion, contributes for instance to successfully using a practical tool (e.g. scissors or hammer) without much conscious effort, as it automatically leads to information on the forces on one's body at a specific point in time, which enables regulation of the muscles, and once experienced, results in automation of actions (Haans & IJsselsteijn, 2012).

Important to realise is that the construction of a body schema, and the experience of proto-presence in general, only leads to motor intentions and not to other sort of intentions (Triberti & Riva, 2016). Motor intentions can be seen as plans for motion or physical action.

An example of a motor intention is “moving my hand like this while holding scissors in order to divide a piece of paper in two”. A high level of proto-presence is needed here in order to correctly estimate the distance between the paper and one’s hand holding scissors as well as to know how much power is required to activate the scissors and to cut the paper. From an evolutionary perspective, proto-presence, and thereby motor intentions, has been constituted by the need to protect our body in the world around us and hence to increase our chance of surviving (Riva et al., 2011).

2.2.1.2 Illustrations of proto-presence in VR

An indicator of perception-action coupling in VR, and thereby the experience of proto-presence, could be found when an user of VR is for instance twisting his/her virtual arms with the aim to find out what belongs to his/her virtual body and what belongs to the virtual environment. Only then the user is able to for example know whether the virtual gloves he/she sees are just lying on top of his/her virtual arms and hence are detached from the virtual body, or whether the virtual gloves are part of the virtual body. When being in VR, this perception-action coupling can have an extra phase compared to real-life perception-action coupling. For users of VR, this process could also involve testing whether his/her virtual legs are matching with the movements of his/her real legs, and hence involves comparing the body schema of the virtual body with the body schema of one’s real body. This could be highly informative for creating a body schema for the virtual body, but also promotes embodiment with respect to the virtual body (Riva & Waterworth, 2013). In order to indicate whether the user is decisively creating a body schema in VR, one can for instance determine whether the user is trying to use all of his/her virtual limbs, as only then it is possible to create a complete body schema (Riva & Waterworth, 2013).

Determining whether the created body schema is correct and whether the user can actually distinguish the virtual self from the virtual environment, can be done in multiple ways. Firstly, one can observe whether the user of VR is aware of the position of his/her virtual body in relation to the virtual environment (Riva & Montavani, 2012). When the user for instance steps on virtual material such as a virtual camera, it is likely that the person is not aware of one’s position. Secondly, one can observe whether the user is able to successfully identify the results of one’s movements (Riva & Montavani, 2012) by for instance determining whether the user is able to activate the camera with care by pressing the power button with one’s finger. Furthermore, one can determine whether the user is able to correctly

estimate the distance in VR (Alshaer et al., 2017) by for instance determining whether the user is able to pick up the virtual camera. By observing the user when he or she is picking up the camera, also the user's hand-eye coordination can be assessed. All things together inform on the quality of an user's body schema as well as one's distinction between the virtual self and the virtual environment, and thereby on the level of proto-presence.

Another indicator of a high level of proto-presence in VR concerns determining whether the user experiences the activities in the VRE through the first-person perspective (Riva & Waterworth, 2013). This can for example be determined by asking the user how he/she perceived the execution of intended actions. The more the participant views the execution of intended actions as embodied intuitive simulations, the more the participant will experience the activities from the first-person perspective, and hence experience more proto-presence (Riva & Waterworth, 2013). In order to examine to what extent the user experienced the intended actions as embodied intuitive simulations, a distinction needs to be made between the experience of a direct action, a first-order mediated action, and a second-order mediated action (Riva & Waterworth, 2013). An user will have the experience of a direct action when he or she for instance had the feeling that he/she was picking up the virtual camera with his/her own arms. The user will experience the execution of an intended action as a first-order mediated action when having the feeling that he/she was taking the virtual camera by using adopted arms from a robot/avatar. Lastly, the user will experience the execution of an intended action as a second-order mediated action when the user had the feeling he/she was using a joystick to move the arms of a robot/avatar when picking up the virtual camera. Importantly, the experience of a direct action will promote proto-presence whereas the experience of a second-order mediated action will diminish proto-presence (Riva & Waterworth, 2013). Noteworthy is that whether the user experiences a direct action, a first-order mediated action, or a second-order mediated action is partly being promoted by immersion, but is mostly determined by personal characteristics such as one's imagination, self-control and concentration, and hence by the level of presence (Psotka & Davidson, 1993).

Another factor that influences the level of proto-presence in VR concerns the pressure of VR equipment and materials on the real body of the user. For instance, when the user is still aware of the weight of the head-mounted display (VR glasses) on his/her real head during the VR experience, this will diminish the level of proto-presence as this is likely to indicate that the user has not been fully immersed in the body feeling and appearance of the avatar as

he/she still experiences body feelings belonging to his/her real-life body (IJsselstein, Ridder, Freeman, & Avons., 2000).

Taking a look at the big picture, experiencing proto-presence leads to for example a VR experience in which an user notices that his or her virtual arm got entrapped in the cable of a virtual camera and realizes that his or her movement is being hindered by that, and in which a person knows how to detach from that virtual cable by for instance making a certain movement with his/her virtual arms (Spagnolli & Gamberini, 2002). Important to realize here is that proto-presence in VR is determined only by form, that is, the means for a convincing bodily and perceptual impression, and not by content of the virtual reality environment (Riva et al., 2004). The reason for this is that proto-presence is only dependent from the physical conditions in the VRE, and not from for instance the comprehensibility of the story within the VRE.

2.2.2 Core presence

2.2.2.1 The concept of core presence

The second neuropsychological layer of presence, core presence, can be interpreted as sensorial presence in the here and now. This layer of presence is on one hand influenced by the level of vividness in the environment, and on the other hand affected by: a) the ability of the person to successfully deal with information that is currently entering his or her sensory channels, and b) the extent to which the person acts towards current actions and events (Riva & Waterworth, 2013). High scores on all three contributors is likely to result in knowing what is happening in the here and now and thereby leading to the notice of for instance encountering objects as well as to possible action towards these objects (Riva et al., 2004). To illustrate, successfully dealing with current clear visible information such as an approaching ball and current clear auditory information such as someone shouting “catch!”, will enable a person to know what is happening in the here and now, and in turn will stimulate the person to act towards this action in terms of preparing him- or herself to catch the ball.

Noticing objects and acting towards them will subsequently result in active encounters with objects that contribute to knowledge on what is expected from the person on each moment. In turn, this helps the person to identify current tasks. For instance, a person’s encounter with a ball will make a person realize “I have the ball now, I should probably do something with it”. Besides this, also a good story promotes proper knowledge and notion on

what is expected from the person at each moment, and hence promotes the identification of current tasks (Riva et al., 2011). In addition, another contributor to knowing what is happening as well as expected in each moment, involves experiencing a high level of vividness in the environment, which helps the person to keep overview of the situation and thereby to successfully direct one's selective attention (IJsselsteijn et al., 2000).

The identification of current tasks will then promote the development of action plans. This happens consciously and requires being conscious of the here and now (Triberti & Riva, 2016). Noteworthy is that the action plans that are being developed in the layer of core presence only involve proximal intentions (Triberti & Riva, 2016). Proximal intentions can be seen as plans for behavior that interact with current events and opportunities. An example of a proximal intention is "Now I will throw the ball into the left side of the goal in order to score a goal". A high level of core presence is needed here in order to realize that: a) one is part of a handball game, b) that one possesses the ball, c) that the goalkeeper is currently standing in the right side of the goal, and d) that one currently has the opportunity to score a goal by throwing into the left side of the goal. In conclusion, core presence is highly dependent on awareness of the current moment, and thereby on awareness of the here and now.

2.2.2.2Illustrations of core presence in VR

One of the main indicators of core presence in VR involves the awareness and correct use of information that is currently entering the sensory channels of the user (Riva & Waterworth, 2013). This can be determined by for instance gauging whether the user tried to read the provided information on the screen of the virtual scanner after scanning a virtual penguin, and hence allowed him/her self to use crucial information. This information could for instance exist of feedback that informs the user about the number of the penguin he or she tracked. After allowing oneself to use this crucial information, the user shows that he/she is able to successfully deal with this information when the user does not stop using the scanner earlier or later than the moment he or she found the penguin with the correct number. Another indicator that indicates whether the user is able to successfully deal with information involves being aware of hints as well as being able to understand these hints. A hint could be direct or indirect. An example of an indirect hint is: "I think your height might be intimidating it". An example of a direct hint is: "Try to kneel down".

Experiencing core presence in VR not only requires awareness and correct use of current information, it also demands a correct distinction between important information and

unimportant information (IJsselstein et al., 2000). Otherwise, an user might be overloaded with to much information and hence will lose overview over the situation. An user of VR can be seen as being capable of making this distinction when successfully directing one's selective attention (IJsselstein et al., 2000). Successfully directing one's selective attention involves for instance that the user is not distracted by for instance the brand of the virtual scanner on the back of the virtual scanner, but that the user is looking at the information on the screen of the scanner. The successful direction of one's selective attention subsequently enables the user to identify current tasks (IJsselstein et al., 2000). By for example asking an user of VR the question "Was it clear to you what you had to do at each moment on Antarctica?", information will be gained on whether an user was able to identify current tasks.

In order to experience core presence in VR, it is not only important that the user can make the distinction between important and unimportant information coming from inside the VRE, but also that he or she is not being aware of information coming from outside the VR environment. Being aware of information (e.g. sounds) from outside the virtual reality is detrimental to the experience of core presence in VR (Biocca, 1997). With this in mind, it is interesting to determine the user's level of sensory satisfaction. The level of sensory satisfaction consists of the percentage of the sensory channel occupied by stimuli from the VR as opposed to stimuli from the physical environment (Biocca, 1997). The higher the level of sensory satisfaction, the more the user experiences core presence (Biocca, 1997).

Another indicator of core presence in VR involves acting towards actions and events in the here and now (Riva & Waterworth, 2013). An user which is for instance trying to get in touch with a virtual penguin that is walking towards him/her, indicates that he or she knows what is currently happening and that he or she is acting towards events that are happening in the here and now. Also an user that turns towards a female virtual person when she starts to speak indicates that he or she is aware of current actions and events and that he or she is acting towards these current actions and events.

Last thing to realize when determining core presence in VR is that it is influenced by both the form and the content that is presented by the VRE (Riva et al., 2004). Thus, it is dependent on the perceptual impression of the physical virtual environment, but also dependent on a meaningful content. For core presence, this dependency on a meaningful content lies in meaning-as-comprehensibility and involves real-time dependency (Riva & Waterworth, 2013). This means that experiencing the content of the VR experience on each

moment as logical and clear is likely to promote core presence. Importantly, being in a VRE that communicates a good story is likely to positively influence the experience of core presence, although the actual experience of core presence is still dependent from how a particular user is dealing with the story (Riva et al., 2011).

2.2.3 Extended presence

2.2.3.1 The concept of extended presence

The third neuropsychological layer of presence, extended presence, can be interpreted as metacognitive presence. This layer of presence is related to the ability of a person to identify the relevance of both the self and its experiences as well as to think about possible actions or scenarios that are not yet present in the current situation (Riva et al., 2011). This requires: a) being conscious of the self in relation with the world, and b) conducting active sense making of the world around us (Triberti & Riva, 2016). Along with the identification of one's relevance and with thoughts about possible actions or scenarios, in this layer, a person will also identify future goals (Riva et al., 2004). In turn, this person will monitor the process towards these goals by means of reflection (Riva et al., 2004).

Besides making plans for the future, in this layer, a person will also be able to look backwards in time, as only in this layer a person is able to look at an experience as a whole and thereby looking both backwards and forward in time (Damasio, 1999), rather than only living in the moment itself which is the case for proto-presence and core presence. This makes it possible to for instance recognize changes in weather. Only in the layer of extended presence a person is able to realize that it is was sunny this morning, but that it is cloudy right now, and that this will probably mean that it is going to rain. Subsequently, a person could aim for remaining dry as he intents to look like a professional scientist during the congress later this day, and therefore decide to bring an umbrella when he is about to leave his house.

All the intentions enacted in the layer of extended presence, such as "I want to look like a professional scientist", are distal intentions (Triberti & Riva, 2016). Distal intentions are mainly conceptual, descriptive or abstract, and are not directly related to a particular action or context (Triberti & Riva, 2016). These intentions are more difficult to achieve than motor- and proximal intentions (Triberti & Riva, 2016). They only started to develop in one of the last stages of the humans' evolutionary process when imaginary conditions became more and more important for surviving and biological success (Riva et al., 2004).

2.2.3.1 Illustrations of extended presence in VR

One of the key requirements for experiencing extended presence in VR is the user's ability to identify the relevance and social role of the virtual avatar that he or she is representing (Biocca, 1997; Riva et al., 2011). For instance, when the user is being placed in the shoes of an Antarctic researcher, he needs to realize that he is an Antarctic researcher from that moment onwards and also needs to become aware of which attitude and motive is suitable for being an Antarctic researcher. By the same token, he needs to be able to determine the rationale and goal behind his and his co-researchers' investigation.

However, it is not only important that the user is able to identify the rationale, but also that the user is seeing the value behind this rationale. More specifically, the experience of extended presence in VR is dependent from the user's attributed significance and value to the tasks that need to be executed, as well as from the relevance, real appearance, and emotional significance of the content (Riva et al., 2004). The user's attributed significance to the experience, both emotional and intellectual, can be determined by for instance asking the user whether he viewed the work belonging to a researcher on Antarctica as relevant. Importantly, whether the user sees the experience as relevant is likely to influence the user's engagement (Riva & Waterworth, 2013). According to Riva and Waterworth (2013) engagement is one of the main prerequisites for experiencing extended presence in VR.

Even if the VRE is highly immersive, an user might still be occupied with personal worries or with people outside the VRE and hence not be fully engaged, maybe because the content presented in the VRE is not engaging for this particular user as some users might be interested in preventing from climate change on Antarctica whereas other users might not be (Riva & Waterworth, 2013). Disengagement will retain the user from metacognitive activities such as thinking from the avatar's perspective, which is likely to diminish experiencing extended presence (Riva & Waterworth, 2013). Besides this, talking to people outside the virtual environment, could indicate that the user does not feel part of the virtual social network, but still feels present in the real-life social network, which means that he is not fully engaged with the social role of the avatar. What must be remembered is that, in the layer of extended presence, an user's engagement only relates to engagement regarding the content, its social role, and to the way the content is made accessible. Hence, extended presence in VR is mainly determined by how mentally and metacognitively engaged the person is as well as

how meaningful in terms of significance the user experiences the content of the virtual environment (Riva et al., 2004).

Lastly, another aspect influencing the level of extended presence in VR concerns the identification of possible actions or scenarios which are not yet present in the current situation, through sense making of the virtual environment (Riva et al., 2011). The identification of possible actions or scenarios for the future can be determined by for instance asking the user whether he or she was thinking about what he or she would do on Antarctica when the other Antarctic researchers would not have given him specific tasks such as the task 'scan the penguin with number 025'. This thinking can concern dreaming and imagination such as "I would have climbed the mountains", but can also be triggered by reflective activities on meta-cognitive level such as "I just left a piece of plastic on the ground, because I did not really think about the bad consequences for nature, but now I realize that a penguin might eat it and, as a consequence, might die". The identified future scenario of a penguin dying because of spilled plastic, could subsequently lead to a possible future action such as starting an awareness campaign about the bad consequences of plastic for nature.

2.3 Measuring presence in VR

There is not only incongruence regarding the concept of presence, but also on how to measure presence in VR. Researchers such as Lombard and Ditton (1997) state that presence can be seen as a dichotomous variable: a person feels either present in real life, or present in the virtual reality. This would imply that there is no classification in presence levels or layers, but that it involves an all-in or nothing phenomenon. However, researchers such as Schubert, Friedmann, and Regenbrecht (1999) have been measuring different and separate subscales of presence that were not mutually inclusive and could vary in level, by developing and using the Igroup Presence Questionnaire on the basis of a factor analysis. The subscales of this questionnaire were based on the media term of presence rather than the neuropsychological term of presence. In the light of the neuropsychological term of presence, researchers Riva, Waterworth, and Waterworth (2004) add to this discussion that it is possible that only one of three neuropsychological layers of presence is experienced in a VRE, which also implies that presence is not a dichotomous variable as these neuropsychological layers are not mutually inclusive, but can occur independently from each other and can vary in extent. For instance, they mention that in case (case 1) you are in a VRE without tracking system, it is still possible

to experience high levels of core presence and extended presence, but it is not likely to experience high levels of proto-presence. To give another example, in case (case 2) the user is located in an immersive VRE, but is still concerned with personal real-life problems, it is still possible to experience proto-presence and core presence in the VRE, but it is less likely to experience extended presence. This is in parallel with a suggestion from Haans (2014), who argues that different measurement items or methods measure a different layer of presence. To explain, when in case 2 one method, for example a behavioural observation list, is merely measuring proto-presence, and the other, for example a questionnaire, is mainly measuring extended presence, it is not surprising to not find a correlation between the methods as the first method will find presence (because proto presence was experienced) whereas the other will find absence of presence (because extended presence was not experienced). Coupled with the neuropsychological definition of presence, this implies that using more than one measurement method and instrument to allow for the three different layers of presence is crucial when aiming for valid research on the level of presence.

However, a majority of the studies only used one method, which is subjective questionnaires, to measure the level of presence (Sylaiou, Liarokapis, Sechidis, & Olga, 2005) although several researchers point out that it is not sufficient to only measure presence through questionnaires (Slater, 2003). The use of only post-experience subjective questionnaires leads to certain dilemmas. Firstly, respondents can have diverse interpretations of questionnaire items, which makes the results incomparable (Slater, Lotto, Arnold, & Sánchez-Vives, 2009). Secondly, post-experience questionnaires can result in reporting a higher level of presence than the actual level of experienced presence by simply arousing presence by mentioning it and by asking questions about it (Slater et al., 2004). Too elaborate on this, there is a lack of independent confirmable data against which to deduce the results from the questionnaire when only using a post-experience questionnaire. This leads to the third dilemma, which implies that only using post-experience questionnaires misses the use of real-time and objective data, which is needed in order to also address users' responses that took place without conscious awareness but also indicate presence (Sylaiou et al., 2005). To clarify this, questionnaires only address the conscious mind whereas physiological measures account for the unconscious mind. Because of the above mentioned dilemmas, some researchers replace the questionnaires by using objective methods such as behavioural observation lists and physiological measures, which mainly address real-time reactions that are conducted without consciousness. However, using an objective method alone is also not

sufficient as self-reports from the participants are needed because presence partly can be considered as a social construction in which persons construct understandings by rationalizing experiences (Villani, Repetto, Cipresso, & Riva, 2012), and in which it is also about how the participant perceives one's position in an environment independent of how this person is acting in this environment (Dalgarno & Lee, 2010). Noteworthy is that questionnaires are less appropriate than for instance interviews as they can lead to misinterpretations or diverse interpretations of the questions. The use of interviews prevents from these dilemmas as the interviewer can determine how the participant interprets the question and can steer the participant in the right direction if needed, or can make notes regarding the different interpretation (Slater et al., 2009).

Nevertheless, little correlation has been found between outcomes when applying diverse measurement methods (e.g. a questionnaire combined with physiological responses) (Slater et al., 2009). As already mentioned, according to Haans (2014) this can be explained by the risk that these methods focus on different layers of presence, and thus should be combined rather than compared. More specifically, the lack of meaningful outcomes might be due to the lack of empirical studies that use a combination of measurement items and methods that allow for all of the different neuropsychological layers of presence, and which put the results in the light of the three layer theory of presence. It is important to realise that an optimal level of presence in VR is only present when all three neuropsychological layers are fully being addressed (Riva & Waterworth, 2013), and therefore these layers should be measured separately and explicitly (and by more than one measurement method), in order to be able to make valid conclusions on the level and sort of presence experienced by the user. To date, and to our knowledge, no empirical study was conducted that has been measuring these layers separately and explicitly. Therefore, it is still unknown whether, and to what extent, the neuropsychological three layer theory of presence is actually applicable to presence in VR and hence whether presence in VR can be considered as a basic neuropsychological phenomenon that involves three different layers of presence. Therefore, it it worthy to investigate whether the categorization into the three neuropsychological layers of presence, which are proto-presence, core presence and extended presence, empirically can be identified when measuring presence in virtual reality.

3. Research Aim

This study aims to investigate to what extent the neuropsychological three layer theory of presence, involving proto-presence, core presence, and extended presence, is applicable to the measurement of presence in Virtual Reality. This induces the following research question:

Research question:

1. Can the categorization into the three neuropsychological layers of presence, involving proto-presence, core presence and extended presence, empirically be identified when measuring presence in virtual reality through the combination of objective and subjective measures?

4. Methods

4.1 Research Design

This study involved a factor analytic study, that gathered multivariate and quantitative data from an objective observation instrument, and multivariate and qualitative data from a subjective semi-structured interview. Both objective and subjective instruments have strengths and weaknesses, and data from both is needed in order to warrant the validity of a presence measurement (Riva et al., 2011). In order to reduce the data collected through these instruments to factors, or in this case to dimensions, a Categorical Principal Component Analysis (CatPCA) was conducted. A CatPCA fits this study as it is an exploratory data analysis method that has the ability to explore underlying dimensions (e.g. different layers of presence) that account for relations among measured items, while optimizing the total of variance accounted for in these items (Linting, Meulman, Groenen, and van der Koojj, 2007). Furthermore, this factor reducing analysis is most appropriate for this study compared to other factor reducing studies as a CatPCA is suitable for categorical data and does not assume linear relationships (Linting et al., 2007).

4.2 Participants

The sample was drawn from both voluntary response sampling and convenience sampling, and included 40 participants (12 male and 28 female). The age of the participants ranged from 18 to 44 years old (M= 21.80, SD= 5.18). All participants were studying at the University of Twente, Enschede, The Netherlands. Hence, the cognitive ability of the participants can be considered as approximately the same. This allows for a fair comparison in terms of participants' understanding, vocabulary, and alignment with the chosen virtual reality environment (Haans, 2014). The majority of the participants concerned students from the Bachelor of Psychology. Furthermore, about a half of the participants had experience with VR before, while the other half did not have VR experience before. Most of the participants were recruited through the test subject pool system of the University of Twente named SONA. The other part was approached in person. All respondents participated individually, and signed an informed consent before participating.

4.3 Instrumentation

4.3.1 VR system and application

This study used the system HTC Vive including both a head mounted display (HMD) and wireless hand controllers, and runned the application "Kolb Antarctica Experience" developed by Devika (see Figure 1). This application took the participants to Antarctica and placed them in the shoes of an Antarctic scientist. Once arrived on Antarctica, the participant first had a bit of time to explore the environment. Then, a fellow virtual researcher introduced herself and told the participant about their current research programme. This researcher told the participant that they needed to understand the ecosystem on Antarctica including the behaviour, and thereby the movement, of the penguins, so that they can protect Antarctica from climate change as well as ensure the penguins a better future. Therefore, other fellow researchers had attached trackers to the penguins in order to collect data on the penguins' movement. The participant was asked to help this research team by capturing a close image of the penguin with number 25, so that this photo could be added to the data of this penguin. In order to do this, the participant was first asked to pick up the virtual scanner and camera from the ground. Subsequently, the participant was asked to find the penguin with number 25 by using the virtual scanner. Before being able to do this, the participant was informed that he had to activate the scanner by pulling and holding the trigger on the back of the scanner.

Then, the participant needed to find the right penguin by scanning the penguins one by one. After finding the right penguin, the screen on the scanner turned green and information regarding the distance this penguin travelled appeared. Subsequently, the participant was asked to make a detailed photo of this penguin to add to this penguin's data. However, before being able to make a detailed photo, the participant was informed that he first needed to draw the penguin closer. The participant was then given some time to find out how to achieve this. After some seconds, the participant received hints that aimed at informing the participant that he should kneel down in order to draw the penguin closer. The first provided hint was an indirect auditory hint ("I think your height might be intimidating it"). When the participant did not act upon this hint successfully, he or she received a second hint which was a combination of an auditory and visual hint and which can be considered as indirect ("It seems that the scientists over there are having luck, take a look at what they are doing"). When needed, the participant was given a third hint which was both direct and auditory, and in which he was explicitly being told that he had to kneel down. After succeeding in making a detailed photo of the penguin, the fellow researcher explained why it was important to collect these records. When the fellow researcher was done telling about the importance, the VR experience came to an end for the participant.

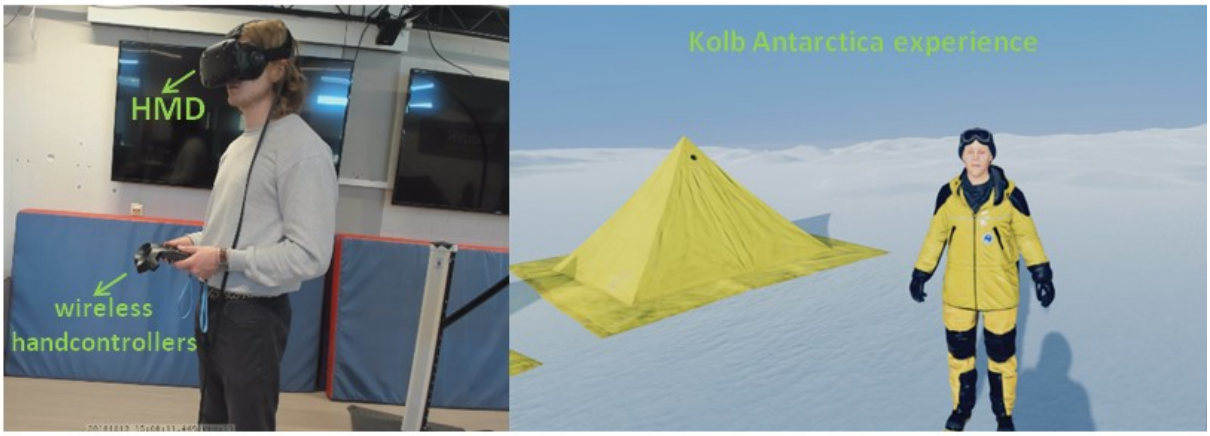

Figure 1. The left picture shows the VR system including HMD and wireless hand controllers; the right picture shows the application Kolb Antarctica Experience.

4.3.2 Behavioural observation list

A behavioural observation list consisting of 13 items was created for this study (see Table 1). These items were based on operationalization of the constructs proto-presence, core presence, and extended presence. Each of the items was expected to be related to only one of

these three constructs. Six items were expected to account for proto-presence. An example of an item that was expected to measure proto-presence is: “The participant twists his/her arms to see if he/she can see both sides of his/her arms.”. Another six items were expected to correspond to core presence. An example of an item that was expected to determine core presence is: “The participants turns towards the female researcher when she starts to speak”. The thirteenth item was expected to measure extended presence. This item is: “The participant continues talking to the researcher in the BMS lab while being in the VR environment.”. The measurement level of the items was either dichotomous or ordinal. An example of a dichotomous item is: “The participant stops using the scanner when he/she found the correct penguin”, whereby either a “yes” or “no can be ticked off. An example of an ordinal item is: “The participant understands that he has to kneel down in order to make a proper picture”. Within this item there are five options to tick: 1) Yes, without any hints or instructions, 2) Yes, but only after a first auditory hint (indirect sign), 3) Yes, but only after the second hint (combination of indirect auditory and visual sign), 4) Yes, but only after the third hint (direct auditory hint) and 5) No. All items were tested during a pilot in order to find flaws and to adjust them accordingly (refer 4.4). This resulted in the observation list (including the observable options) included in Appendix A. The behaviour of the participants was recorded through the software iMotions and was filmed from both the VRE perspective and the real-life perspective. The VRE perspective involved what the participant saw through the VR glasses (refer Figure 2), and the real-life perspective concerned seeing the test subject wearing a HMD and hand controllers and making movements in the real-life lab (refer Figure 2). The latter was filmed from two different perspectives in the lab.

Table 1

Observation items included in this study categorized per layer

#	Item	Measurement level	Layer
1.	The participants turns towards the female researcher when she starts to speak.	Ordinal	Core presence
2.	The participant is moving one’s his/her whole body when looking around	Ordinal	Proto-presence
3.	The participant is explicitly testing whether his/her virtual legs matches the movements with his/her real legs.	Dichotomous	Proto-presence
4.	The participant twists his/her arms to see if he/she	Ordinal	Proto-presence

	can see both sides of his/her arms.		
5.	The participant steps on the virtual canvas underneath the virtual scanner and camera, or on the virtual scanner or camera itself.	Ordinal	Proto-presence
6.	The participant succeeds in picking up the virtual scanner and camera.	Ordinal	Proto-presence
7.	The participant tries to walk to them virtual penguin in order to make a proper picture.	Ordinal	Proto-presence
8.	The participant stops using the virtual scanner when he/she found the correct penguin.	Dichotomous	Core presence
9.	The participant is distracted from the task and tries to make pictures of other things than the penguin.	Dichotomous	Core presence
10.	The participant acts upon the green checkmarks and the red crosses popped up on the virtual camera until the goal is achieved.	Dichotomous	Core presence
11.	The participant understands that he/she has to kneel down in order to make a proper picture.	Ordinal	Core presence
12.	The participant tries to get in touch with the virtual penguin that walked towards him.	Ordinal	Core presence
13.	The participant continues talking to the researcher in the BMS lab while being in the VR environment.	Ordinal	Extended presence

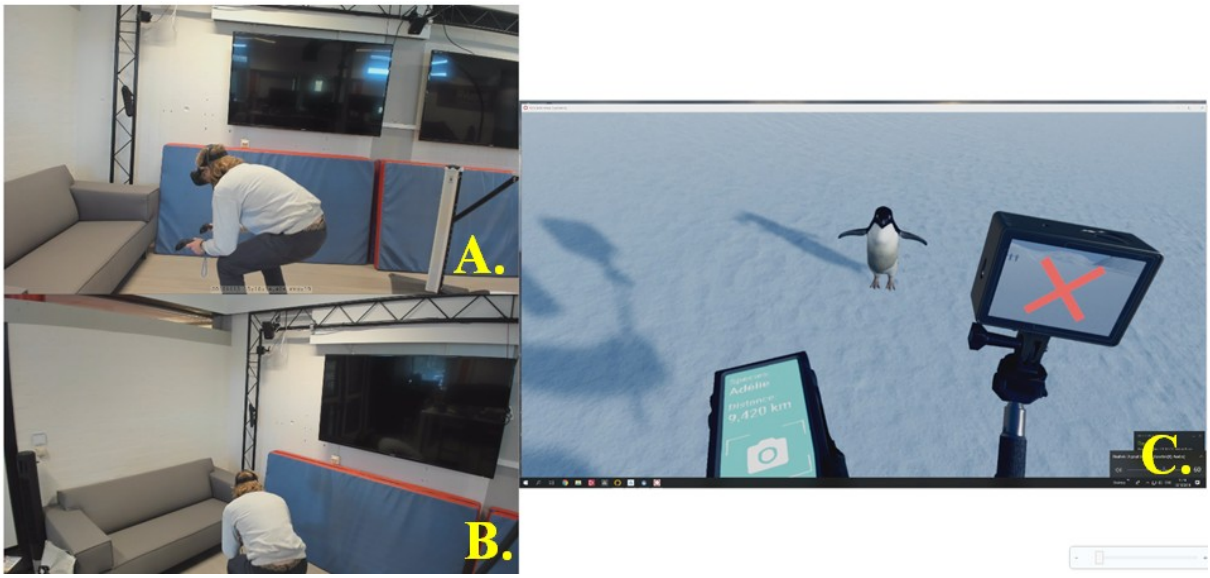

Figure 2. Video recordings from three different perspectives. Printscreen A. and B. show how the researcher saw the test subject behaving in the lab. Printscreen C. shows what the participant saw through the VR glasses, and also shows the consequences of the participant 's actions in the VRE.

4.3.3 Self-reports through semi-structured interview

A semi-structured interview consisting of 10 items was created in order to gather subjective self-reports. These items were based on operationalization of the constructs proto-presence, core presence, and extended presence. Each of the items was expected to relate to only one of the three constructs. Two of the items were expected to determine proto-presence. An example of an item measuring proto-presence is: "Did you still feel the weight of the headset on your head when you were on Antarctica?". Three of the other items were expected to relate to core presence. An example of an item measuring core presence is: Did you hear sounds from outside the virtual reality application when you were on Antarctica?". The other five items were expected to determine extended presence. An example of an item measuring extended presence is: "Where you thinking about things that did not have anything to do with being on Antarctica when you were in the virtual environment of Antarctica?". A pilot study was run to check whether the items were appropriate and easy to interpret. This resulted in the questions that can be found in Table 2. This interview lasted around 10 to 15 minutes.

Table 2
Interview items used in this study categorized per layer of presence

#	Item	Layer	i
1.	Did you hear sounds from outside the virtual reality application when you were on Antarctica? When? And which sounds?	Core presence	
2.	Did you still feel the weight of the headset on your head when you were on Antarctica?	Proto-presence	
3.	Could you tell me what the Antarctic researchers were investigating on Antartica?	Extended presence	
4.	Do you view the work of the Antarctic researchers you met on Antarctica as important?	Extended presence	
5.	Do you know what information was shown on the scanner after you scanned the correct penguin?	Core presence	
6.	Where you thinking about things that did not have anything to do with being on Antarctica when you were in the virtual environment of Antarctica?	Extended presence	
7.	Where you thinking about what you would do on Antarctica when the Antarctic researchers would not have given you these specific tasks with the scanner and camera?	Extended presence	

8.	Was it clear to you what you had to do at each moment on Antartica? So, what your tasks were and how to achieve them?	Core presence
9.	How did you feel when you were picking up the scanner and camera from the ground: a) did you feel like you were taking the scanner and camera with your own arms, b), like you were taking the scanner and camera by using adopted arms from a robot, or c) like you were using a joystick to move the arms of a robot?	Proto-presence
10.	Did you enjoy having this VR experience?	Extended presence

4.3.4 Igroup Presence Questionnaire (IPQ)

In addition to the self-reports through semi-structured interviews, 11 questions from the Igroup Presence Questionnaire (IPQ; Schubert, Friedmann & Regenbrecht, 1999) were used to test convergent validity regarding the behavioural observation list and the semi-structured interviews. The IPQ involves four subscales: General Presence (PRES), Spatial presence (SP), Involvement (INV) and Experienced Realism (REAL). The PRES subscale determines the general sense of being there. An example of an item measuring General Presence is: “In the computer generated world I had a sense of "being there". The SP subscale measures the feeling of being physically present. An example of an item measuring SP is: “I had a sense of acting in the virtual space, rather than operating something from outside”. The INV subscale addresses the participant’s perceptions regarding his or her attention and involvement in the VRE. An example of an item measuring the INV is: “I still paid attention to the real environment”. The REAL items measure the extent to which the participant experienced the VRE as real. An example of an item measuring the REAL is: “How real did the virtual world seem to you?”. Appendix B shows all the questions and statements from the IPQ that were used. The participant could indicate on a scale from 0 to 7 to which extent he/she agreed. In order to assess the reliability of the participant’s responds, the Cronbach’s α of each subscale was determined.

4.4 Pilot study

In order to find flaws in the measurement items, a pilot study was conducted. One female participant with the age of 25 participated in this pilot study. This pilot study led to one modification in the instructions provided to the participant, and to two modifications in the observation instrument. No changes were needed in the semi-structured interview. In light

of the instructions provided to the participant, in both the informed consent and the instructions on site, the participant was told that a female researcher would give further instructions after arriving on Antarctica. The participant in the pilot study indicated that this information had triggered her to immediately search for and turn towards the female researcher when she arrived on Antarctica, because she knew she would receive further information from her. This implies that this information influences the participant's behaviour regarding observation item 1, which runs as follows: "The participants turns towards the female researcher when she starts to speak.". Therefore, this information has been excluded in both the informed consent and the information on site.

Another flaw identified during the pilot study concerns the lack of concreteness in one of the observation items. It concerned the following observation item: "The participant is using all of his/her limbs (including head, arms, legs, and feet)". This item was not concrete enough and needed to be split up in more than one observation items. Observation item 3 and 4 were already determining whether the participant is testing his/her legs and arms, which can be considered as an more advanced state of simply using these limbs. As an observation item regarding simply using one's legs can be seen as a more easy accessible observation item and thus a more common item, such kind of observation item should also be included in order to allow for different accessibility levels within proto-presence. The formulation of such item was stimulated by the participant's behaviour during the pilot study. When the participant in the pilot study was situated in the virtual environment, she tried to ask the researcher whether or not she could walk to the penguin. This means that she did not know to what extent she could use her legs. Her question concerns a question regarding her virtual physical state and abilities, which influences the experienced proto-presence. So, in order to determine whether a participant is simply using his/her legs, the following observation item has been added: "The participant tries to walk after the penguin in order to make a proper photo". The researcher will then indicate if the participant does walk to the penguin with more than 3 steps, with less than 3 steps or not at all. Whether the participant is using his/her arms, was already indirectly being measured by observation item 6. This means that the use of one's head and trunk was still left to be measured. Therefore, the following observation item has been added: "The participant is moving his/her whole body when looking around". The observer then checks one of three following options on the observation list: a) Whole body, b) Only neck/head, c) Not looking around at all.

Lastly, during the pilot study it was also found that it is difficult to see whether or not the participant is explicitly looking at the information showed on the screen of the virtual scanner after scanning a virtual penguin. The observation item "The participant tries to read the information on the scanner by bringing the virtual scanner closer to his/her face" was supposed to determine this. In the pilot study, the participant did not bring the scanner closer to her face and did also not really turn the scanner to get a better view on it. Nevertheless, the participant was able to tell what information was shown on the scanner, because it was possible to read the information from a distance and without turning it. Therefore, this observation item has been translated in an interview question which runs as follows: "Do you know what information was shown on the scanner after you scanned a penguin?".

4.5 Procedure

Prior to data collection, the ethics commission of the University of Twente was asked for approval. Also, before the participants participated in this study, they were informed on the aim, benefit, procedure, risks and rights related to this study (refer Appendix C), and were asked for consent regarding their participation as well as regarding the video recordings (See Appendix C). All respondents participated individually and were placed in the exact same condition, one at the time. The experiments were conducted in the BMS lab of the university of Twente, under supervision of the researcher. All the to-be provided instructions and to-be conducted actions by the researcher can be found in Appendix D. After the participant gave consent, the participant firstly was given a HMD and wireless hand controllers including explanation, and was asked to take place in the VRE. The VR experience had a duration between 5 and 8 minutes. In case the participant was not finished after 9 minutes, the participant was asked to take off the HMD as this implied the participant got lost. After the VR experience, the participant was asked to take part in the semi-structured interview. This interview was conducted by the researcher and lasted between 10 and 15 minutes. The answers from the participant were recorded by the researcher by making notes of the received answers. After finishing the interview, the participant was asked to fill in the IPQ questionnaire. This took no longer than 10 minutes. Subsequently, the respondent was given the opportunity to make remarks, ask questions and to subscribe for the final report of the study. Lastly, to prevent from validity threats the participant was asked to not share information regarding the VR experience and questionnaire.

4.6 Data analysis

4.6.1 Semi-structured interviews

Data from the semi-structured interviews was analyzed, categorized and coded. The analysis process involved three phases: 1) open coding, 2) axial coding, and 3) selective coding. By going through these three phases, all relevant categories were identified in a structured and progressive manner. The first phase, that is, open coding, concerned an inductive approach and involved a process in which tentative labels were assigned to the data by reading through the data in a repetative fashion. The corresponding unguided interpretation of the data and the constant comparison between chunks in the data, contributed to the avoidance of subjectivity and bias (Corbin & Strauss, 1990). In the second phase, that is, axial coding, the resulting codes from the first phase were broken down into further developed core categories and corresponding sub-categories, by both inductive and deductive coding. In this phase, deductive coding has been conducted in an attempt to link the data to the existing theory about proto-presence, core presence and extended presence, in order to understand the data from a theoretical perspective. The third phase, that is, selective coding, aimed at classifying all the categories around the overarching themes (i.e. layers of presence). Through this process, the conceptual density of the categories as well as the explanatory power of the overarching themes was tested (Corbin & Strass, 1990). Furthermore, the third phase was also used to further explicate the categories by adding descriptive fine points. The resulting overarching coding scheme can be found in Appendix E. This coding scheme exists of individual coding schemes per interview question. All the codes in each coding scheme were awarded points regarding presence so that the total score per presence layer as well as the total score of presence in general, could be determined. After coding the data, the data was analysed using SPSS.

In order to assess the reliability of the content analysis, a second coder was asked to re-code the answers from 10 participants. According to Lombard, Snyder-Duch, and Bracken (2002) 10% of the total content coded by a second coder is sufficient. This resulted in a Cohen's Kappa score of 0.96, which can be considered as strong (Cohen, 1960). The differences in coding were discussed with the second coder, and subsequently consensus on the coding scheme was reached.

4.6.2 Observations

Data from the observations was analysed using SPSS, together with the data resulting from the semi-structured interviews. All data was subjected to a Categorical Principal Component Analysis with a spline ordinal scaling level. The spline ordinal scaling level was chosen because it provides more natural outcomes for original ordered categories as it retains this information most optimally (Manfredi, Manisera, and Dabrassi, 2009). The evaluation of goodness of fit was established based on the Cronbach's Alpha values per dimension as well as on the Total Variance-Accounted-For. Those indicators enable a proper comparison between solutions corresponding to different numbers of dimensions (Manfredi et al., 2009). Furthermore, all data corresponding to the same theorized layer of presence was subjected to the Cronbach's Alpha coefficient in order to assess the reliability of the items that were proposed to correspond to the same neuropsychological layer.

4.6.3 IPQ questionnaires

Data from the IPQ questionnaires was used to warrant the convergent validity of the new developed presence measure, by correlating the total score of presence experienced by a person measured by the existing IPQ measure with the total score of presence experienced by a person measured by the new measure, using SPSS. To determine the subscale reliabilities of the IPQ questionnaire in this study, the Cronbach's α of the subscales was computed and was .75 (SP), .72 (INV) and .66 (REAL). The Cronbach's α for the PRES subscale could not be established as this subscale only involved one item. As can be seen in Table 3, the subscale reliabilities found in this study conform with the average Cronbach's α per subscale found in two studies done by Igroup (Schubert et al., 1999.)

Table 3
Subscale reliability of the IPQ determined through Cronbach's α. The left column shows the avarage reliabilities found in two studies conducted by Igroup; the right column shows the reliabilities found in this study.

Subscale	**Cronbach's α of studies done by Igroup**	**Cronbach's α of current Study**
SP	.785	.745
INV	.760	.719
REAL	.690	.655

5. Results

5.1 The categorization into proto-presence, core presence and extended presence

In order to explore whether the categorization into the three neuropsychological layers of presence, involving proto-presence, core presence and extended presence, empirically can be identified when measuring presence in virtual reality, all measurement items except for observation item 10, were subjected to a Categorical Principal Component Analysis (CatPCA) with a spline ordinal scaling level and none rotation (refer Table 4). Observation item 10 was excluded from the CatPCA analysis as this item involved zero variance. Based on the "eigenvalue greater than one" criteria and on criteria regarding satisfactory Cronbach's Alpha values per dimension, the analysis revealed four dimensions. These four dimensions explained 47.92 of the total variance for the complete set of variables. Each of these dimensions had a satisfactory value for Cronbach's Alpha (respectively being .75, .70, .68, and .63) (Taber, 2018). Within these dimensions, only items that load higher than .45 were retained.

The first dimension included eight items, which are: a) The participant is moving one's whole body when looking around, b) The participant is explicitly testing whether his/her movements match the movements with his/her real legs, c) The participant stops using the scanner when he/she found the correct penguin, d) The participant is distracted from the task and tries to make pictures of other things than the penguin, e) The participant tries to get in touch with the penguin that walked towards him, and f) Could you tell me what the Antarctic researchers were investigating on Antarctica, g) Could you indicate how important the work of the Antarctic researchers felt on a scale from 0 to 10?, and h) Was it clear to you what you had to do at each moment?. The first two items (a and b) in this dimension were expected to relate to proto-presence. Four of the other items in this dimensions (c, d, e and h) were expected to correspond to core presence, and the remaining two items (f and g) were expected to account for extended presence. This means that in this dimension no categorization into the same neuropsychological layer was found. Within this dimension, all items loaded positively. Generally, this means that a person is likely to score high on each individual item in this dimension when this person also scores high on the other items in this dimension. What all these items might share is determining the participant's general focus on affordances. In other words, they might all measure to what extent the participant is focused on what the virtual environment has to offer in terms of information about where the

environment is meant for. Dimension 1 explained 14.26 percent of the variance and had an eigenvalue of 3.57.

The second dimension included five items, which are: a) The participant turns towards the female researcher when she starts to speak, b) The participant understands that he/she has to kneel down in order to make a proper picture, c) Do you know what information was shown on the scanner when you scanned the correct penguin?, d) Were you thinking about other things that did not have anything to do with being on Antarctica when you were in the virtual environment of Antarctica?, and e) Did you enjoy having this VR experience?. The first three items (a – c) were expected to account for core presence, and the latter two items (d and e) were expected to relate to extended presence. This means that in this dimension no categorization into the same neuropsychological layer was found. Within this dimension, four items (a, b, c, and e) loaded positively and one item (d) loaded negatively. This means that one item (d) has a negative influence on this dimension. Generally, this indicates that a person which is thinking about things that do not have anything to do with being on Antarctica when he/she is in the virtual environment of Antarctica, is less likely to: turn towards the female researcher when she starts to speak, understand that he/she has to kneel down in order to make a proper picture, know what information was shown on the scanner when he/she scanned the correct penguin and enjoy the experience, and vice versa. This might imply that all the items relate to or have influence on the sensorial management of the person. This dimension explained 12.13% of the variance, and had an eigenvalue of 3.03.

The third dimension included the following four items: a) The participant is explicitly testing whether his/her virtual legs match the movements with his/her real legs, b) The participant tries to get in touch with the penguin that walked towards him/her., c) Do you view the work of the Antarctic researchers you met on Antarctica as important (rationally)?, and d) How did you feel when picking up the virtual scanner and camera?. The first item (a) was expected to account for proto-presence, the second (b) for core presence, the third (c) for extended presence, and the fourth (d) for proto-presence. This means that in this dimension no categorization into the same neuropsychological layer was found. Within this dimension, item a, item b and item d loaded positively and item c loaded negatively. This implies that item c has a negative correlation with dimension three. Generally, this indicates that a person that views the work of the Antarctic researchers rationally as important, is less likely to: explicitly test whether his/her virtual legs match the movements with his/her real legs, get in touch with the penguin that walked towards him/her and to feel as if he/she were taking the

virtual scanner and camera with his/her own arms and thereby experiencing the experience from a first-person perspective, and vice versa. All the items in this dimension might be considered as determining to what extent the actions of the person are driven by form. This dimension, explained 11.43% of the variance, and had an eigenvalue of 2.86.

The fourth dimension included these four items: a) The participant steps on the virtual canvas underneath the virtual scanner and camera, or on the virtual scanner or camera., b) The participant succeeds in picking up the virtual scanner and camera, c) The participant tries to walk to the penguin in order to make a proper picture, and d) Intuition: Could you indicate how important the work of the Antarctic researchers felt on a scale from 0 to 10?. The first three items (a-c) were expected to correspond to proto-presence, and the last item (d) was expected to relate to extended presence. This means that three of the four items related to the same neuropsychological layer. Item b had a positive influence on dimension four, and the other items (a, c, and d) had a negate influence on dimension four. Generally, this indicates that a person that immediately succeeds in picking up the virtual scanner and camera without trial and error, is less likely to: step on the virtual canvas underneath the virtual canvas, walk to the penguin in order to make a proper picture and to view the work of the Antarctic researchers intuitively as important, and vice versa. This might relate to how much activity is needed in order to survive the virtual situation in terms of feeling challenged to manage the situation. This dimension explained 10.10% of the total variance, and had an eigenvalue of 2.53.

In conclusion, the dimensions show an overlap of items that were expected to relate to either proto-presence, core presence or extended presence. This means that no clear categorization into proto-presence, core presence and extended presence was identified. The low Cronbach's Alpha scores per proposed neuropsychological layer including the expected corresponding items (refer Table 5) support this finding, with the highest value being .52 for the layer extended presence. The Cronbach's Alpha for proto-presence was only .21, and for core presence this score was .40.

Table 4

Dimension loadings based on the categorical principal component analysis with none rotation for 25 measurement items (N=40)

	Loadings			
Item	**1**	**2**	**3**	**4**
O2: The participant is moving one's whole body when looking around.	**.513**			
O3: The participant is explicitly testing whether his/her virtual legs match the movements with his/her real legs.	**.484**		**.496**	
O8: The participant stops using the scanner when he/she found the correct penguin.	**.480**			
O9: The participant is distracted from the task and tries to make pictures of other things than the penguin.	**.548**			
O12: The participant tries to get in touch with the penguin that walked towards him/her.	**.540**		**.660**	
Q3: Could you tell me what the Antarctic researchers were investigating on Antarctica?	**.603**			
Q4B: Intuition: Could you indicate how important the work of the Antarctic researchers felt on a scale from 0 to 10?	**.571**			**-.478**
Q8: Was it clear to you what you had to do at each moment on Antarctica?	**.519**			
O1: The participant turns towards the female researcher when she starts to speak.		**.648**		
O11: The participant understands that he/she has to kneel down in order to make a proper picture.		**.618**		
Q5A: Do you know what information was shown on the scanner after you scanned the correct penguin? – What kind of information		**.565**		
Q6: Where you thinking about things that did not have anything to do with the virtual reality experience?		**-.610**		
Q10A: Rationalization: Did you enjoy having this VR experience?		**.520**		
Q4A: Rationalization: Do you view the work of the Antarctic researchers you met on Antarctica as important?			**-.584**	
Q9: How did you feel when you were picking up the scanner and camera from the ground?			**.478**	
O5: The participant steps on the virtual canvas underneath the virtual scanner and or camera, or on the scanner of camera.				**-.617**
O6: The participant succeeds in picking up the virtual scanner and camera.				**.616**
O7: The participant tries to walk to the penguin in order to make a proper picture.				**-.585**
Cronbach's Alpha	.750	.698	.677	.629
Eigenvalue	3.566	3.033	2.856	2.525
% of Total Variance	14.263	12.134	11.425	10.102

	Total Variance	**47.923**

Note: Factor loadings over .45 appear in bold.

Table 5
Reliability per neuropsychological layer through Cronbach's α.

Layer	**Cronbach's α**
Proto-presence	.271
Core presence	.396
Extended presence	.523

5.2 Convergent validity of the measurement instruments

The convergent validity of the new developed measurement instruments was tested by correlating the new instruments with an existing measure: the IPQ questionnaire. Each participant's total score of presence determined by the new developed measurement instruments was compared with one's total score of presence measured by the IPQ questionnaire. For determining the total score of presence indicated by the new instruments, all the different categories of responses determined by the observations and the interviews was awarded points with respect to presence, and were then added up to find the total score of presence per participant. The total score of presence per participant determined by the IPQ questionnaire was found by adding up all the given rates per item. The new developed measurement instruments correlated significantly at a 0.01 level with the existing IPQ questionnaire ($r= .433$, $p=.005$). This means that the convergent validity of the new developed measurement instruments was warranted.

6. Discussion

In order to investigate whether the use of virtual reality in education could be effective, it is first crucial to know how to best measure presence, as the possibility to feel presence in educative virtual reality environments is what makes this medium distinctive, and thereby promising, compared to other learning media. From a literature review, it was concluded that presence in virtual reality is expected to be measured most firmly by applying a neuropsychological approach, as presence can be considered as a basic neuropsychological phenomenon rather than a construct specifically attributed to VR. Neuropsychologically, it was theorized that presence can be split into three functionally different layers, which are

proto-presence, core presence and extended presence. This theory was called the neuropsychological three layer theory of presence. The main goal of this study was to explore the extent to which this neuropsychological three layer theory of presence is applicable to the measurement of presence in Virtual Reality. More specifically, this study investigated whether the categorization into the three neuropsychological layers of presence, involving proto-presence, core presence and extended presence, empirically could be identified when measuring presence in virtual reality through the combination of objective and subjective measures.

In the light of the three neuropsychological layers of presence, Riva et al. (2004) note that in a VRE without tracking system, it is still possible to experience high levels of core presence and extended presence, but it is not likely to experience proto-presence. This would imply that the three neuropsychological layers of presence are not mutually inclusive, but rather can occur independently from each other. Correspondingly, they stress that there is a clear conceptual distinction between the layers, and that each layer is characterized by specific features. Nevertheless, results from this study indicate that there is overlap between the three neuropsychological layers when studying these layers empirically, and hence an empirical distinction between the layers proto-presence, core presence and extended presence when measuring presence in VR could not be identified. Possible contributors to this overlap are depicted in figure 3, and are described and explained below on the basis of the revealed dimensions in this study. Thereafter, the results will be discussed in a more general fashion.

6.1 Main research outcomes

6.1.1 Research outcomes in the light of the revealed dimensions

The first dimension resulted from the CatPCA included two items that were expected to correspond to proto-presence, four items that were expected to relate to core presence, and also two items that were expected to account for extended presence. Hence, no categorization into the same neuropsychological layer of presence was found in this dimension. After a thorough inspection of this dimension, it was suggested that all the items in this dimension seem to be directed at determining the participant's general focus on affordances. This means that all these items seem to measure to what extent the participant is focused on what the virtual environment has to offer in terms of information about where the environment is meant for. This information could inform about series of functions, supplies, correctitude and

importance, and thereby enabling a person to identify appropriate and potential paths of action (Triberti & Riva, 2016). These appropriate and potential paths of action go hand in hand with intentions. For example, when a person recognizes the environmental affordances which make it possible and desirable to track a penguin, such as the availability of a scanner, being able to read information on the scanner and having encounters with penguins, could lead to the intention "now I will scan a penguin to know the distance it travelled". As mentioned earlier, a person can have three different sort of intentions: motor-intentions, proximal intentions and distal-abstract intentions (Triberti & Riva, 2016). Each of these sorts of intentions was suggested to be enacted in another neuropsychological layer of presence. Also, it was suggested that these intentions could exist independently from each other. However, each of these sorts of intentions is dependent from the environmental affordances and thereby jointly dependent from identifying the environmental affordances (Triberti & Riva, 2016). This means that a general focus on environmental affordances, rather than a concrete focus, has consequences for all sorts of intentions and thereby for each and every layer of presence. These consequences are expected to relate to each other, which would imply that the three layers of presence do not just coexist but that they are intertwined. For example, when identifying environmental affordances in general leads to the proximal intention "now I will scan a penguin to know the distance it travelled", this intention is likely to go hand in hand with for example the motor intention "I move my fingers on the scanner this way to scan a penguin" and the distal intention "I want to research penguins' movement in order to safe them". Thus, a possible explanation for the overlap between the three layers found in the first dimension could be that a general focus on environmental affordances is likely to influence each layer and thereby is intertwining the layers, which retains from categorization into proto-presence, core presence and extended presence.

The second dimension resulting from the CatPCA included three items that were expected to relate to core presence and two items that were expected to correspond to extended presence. The overlap between core-presence and extended presence found here, could be explained from a shared dependence by core- and extended presence on conscious and interpretative effort. Proto-presence mostly happens unconscious and does not require interpretative effort, whereas both core presence and extended presence do require conscious and interpretative effort (Riva & Waterworth, 2013). When having a close look at the items revealed in the second dimension, all these items seem to relate to or have influence on active and successfull sensorial management of the person. Successfull sensorial management only

happens when one is conscious of incoming information in his/her sensory channel as well as when one can interpret the incoming information both correctly and actively. Therefore, conscious and interpretative effort is required for successfull sensorial management. Items in dimension two that are expected to indicate whether active sensorial management was taken place are: a) The participant turns towards the female researcher when she starts to speak, b) The participant understands that he/she has to kneel down in order to make a proper picture, and c) Do you know what information was shown on the scanner when you scanned the correct penguin?. The other two items revealed in this dimension seem to influence whether the sensorial management is successfull. One of these items runs as follows "Where you thinking about other things that did not have anything to do with being on Antarctica?". This item was expected to relate to extended presence as a person that is still occupied with personal worries or other personal things will be retained from thinking from the avatar's perspective and thereby retaining him/her from metacognitive activities related to the role of the avatar. However, when a person is thinking about other things such as personal worries, this is also likely to impede this person from being conscious of incoming information in his/her sensory channel or to interpret this information correctly, as his/her attention is partly reserved for his/her worries rather than for the incoming information in his/her sensory channel. The fifth item in this dimension was: Did you enjoy having this VR experience?. Also this item has influence on the sensorial management of a person as engagement partly goes hand in hand with conscious and interpretative effort. In the first place, it was expected that the engagement of the participant would only influence the level of extended presence. Yet, during the selective coding phase of interview item 10, interesting insights with attention to engagement in VR were gained by conducting a more in-depth literature review on this phenomenon. It was found that there are three different forms of engagement in VR: engagement related to immersion, engagement related to presence in general, and engagement specifically related to extended presence. While these kinds of engagements are being used interchangeably, there is a significant difference between these kinds of engagement (Douglas & Hargadon, 2001). Douglas and Hargadon (2001) point out that engagement related to immersion concerns unconscious involvement, whereas engagement related to presence in general as well as to extended presence asks for a more conscious and interpretative effort. In detail, engagement related to immersion is enacted and canned by the hardware, and concerns unconscious involvement, because the VRE goes beyond the user's imagination by identifying and responding to the position of the user in the VRE. On the contrary, engagement corresponding to presence and extended presence requires enactment by the user

through conscious and interpretative effort, such as imagination and reflection. In addition, there is also a difference between engagement related to presence in general and between engagement in the light of extended presence. Engagement specifically attributed to extended presence only involves engagement regarding the content or how the content is made accessible, whereas engagement corresponding to presence in general could also concern engagement regarding the form (Riva et al., 2004). Thus, a possible explanation for the overlap between core presence and extended presence found in dimension two, could be the shared dependence by core- and extended presence on conscious and interpretative effort, which is, amongst others, needed for successfull sensorial management of the person, and which is influenced by engagement regarding presence in general and extended presence in specific.

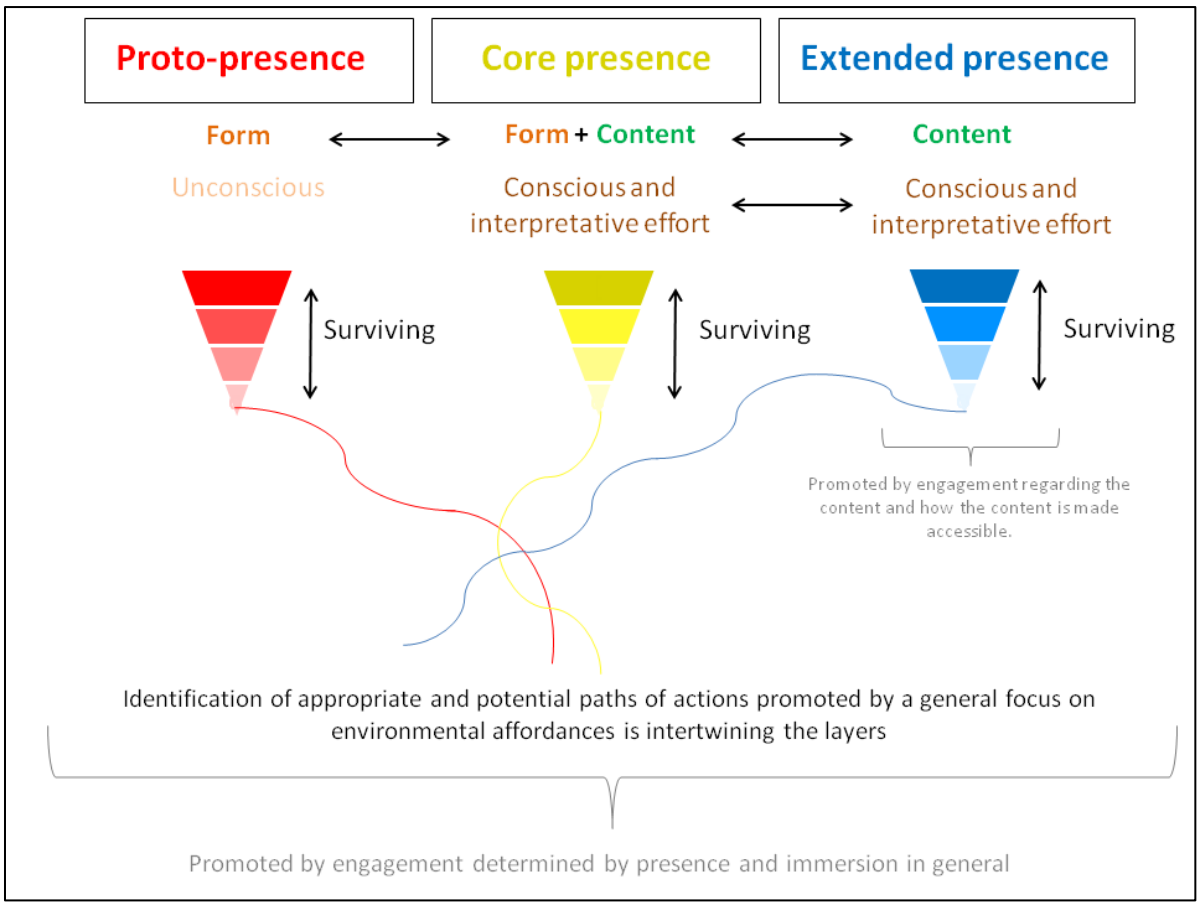

Figure 3. The overlap between the neuropsychological layers of presence.

The third dimension resulted from this CatPCA included two items that were expected to correspond to proto-presence, one item that was assumed to relate to core presence and one item that was expected to account for extended presence. The overlap between the three layers in this dimension might be explained from a shared focus on determining to what extent the

actions of a person are driven by form. Actions in the layer of proto-presence as well as in the layer of core presence are dependent from the form of the virtual environment, whereas actions in the layer of extended presence are only dependent from the content of the virtual environment. By form is meant what the physical environment offers the person in terms of a bodily and perceptual impression (Riva et al., 2004). The items in the third dimension that test whether a person is actively acting upon a bodily and perceptual impression are: a) The participant is explicitly testing whether his/her virtual legs match the movements with his/her real legs, b) The participant tries to get in touch with the penguin that walked towards him, and c) How did you feel when picking up the virtual scanner and camera?. The remaining item in this dimension, which was expected to account for extended presence, has a negative influence on this dimension, and thereby a negative influence on the extent to which actions of a person are driven by form. This item runs as follows: Do you view the work of the Antarctic researchers you met on Antarctica as important? Could you explain?. An explanation for the negative influence of this item on the extent to which actions of a person are driven by form, could be that when a person views the work of the Antarctic researchers he/she met on Antarctica as rationally important and relevant, this person is more promoted to also conduct actions driven by content as the experience of extended presence is likely to increase, which might diminish the extent to which actions are driven by form.

The fourth dimension revealed in this study included three items that were expected to account for proto-presence and one item that was expected to relate to extended presence. This dimension revealed that a person that immediately succeeds in picking up the virtual scanner and camera without trial and error, is less likely to: step on the virtual canvas underneath the virtual camera and scanner, walk to the penguin in order to make a proper picture, to view the work of the Antarctic researchers intuitively as important, and vice versa. This might relate to how much activity is needed in order to survive the virtual situation and hence the extent to which the participant feels challenged to manage the situation. The more a person is present in significant and challenging experiences, the more the need to survive is present and the more actions and intentions are being enacted in each layer (Riva et al., 2004). In case a person notices that he/she can pick up the virtual scanner and camera without much effort and without trial and error, by just bringing his/her upper body and arms only a little bit to the front, then it is likely that a person feels less challenged to walk or to see or feel the importance of both his own work and the work of the Antarctic researchers. This can be supported by information gained from the semi-structured interviews. Some of the

participants indicated during the semi-structured interviews that they compared their own task as a researcher in de virtual world against the work of the Antarctic researchers in general when assessing the importance of the Antarctic researchers' work, and on the basis of the simplicity of their own task, they said that they did not see the work of the Antarctic researchers as important and thereby not motivating. In parallel, the absence of the need to survive or the attempt to successfully manage the situation in this virtual environment in general, could have been detrimental to high enactment of actions and intentions at each layer, and thereby could have been detrimental to a clear empirical categorization into proto-presence, core presence, and extended presence.

6.1.2 Research outcomes in a general light

In general, the results of this study seem to indicate that the neuropsychological three layer theory of presence is not fully and directly applicable to the measurement of presence in Virtual Reality. This is not consistent with the neuropsychological view on presence, which states that the concept of presence as a basic psychologic phenomenon is not different from the concept of presence in VR. However, some of the researchers that represent the neuropsychological view on presence in VR, note some differences between real-life and virtual life that are likely to influence the experience of presence (Riva & Mantovani, 2000; Waterworth and Waterworth, 2003; Riva et al., 2004). There are differences with respect to form, identification of imagination, the social-cultural condition, and the importancy of the layers of presence.

In real-life, presence is not dependent from the form (Riva et al., 2004). Presence in real-life is only reliant on the content, thus on the extent to which our past, current and future experiences are meaningful in terms of comprehensibility as well as in terms of significance. The reason why presence in real-life is not dependent from form is that in real-life the form is automatically arranged and suitable due to natural circumstances. This means that in real-life, proto-presence is always being experienced. In contrast, in VR, proto-presence is the most complicated layer of presence to experience (Riva et al., 2004). There are two reasons for this. Firstly, when someone is inside a medium, it is expected that this person never feels fully separated from his/her physical position and state in real-life, and therefore never fully experiences proto-presence corresponding to the virtual situation. Secondly, experiencing proto-presence in VR requires great technical qualities which are currently still complicated to

reach. These shortcomings in technical qualities retain persons to fully experience proto-presence.

Not only the dependency on form is what differs between real-life and virtual life, there is also a difference regarding the identification of imagination when comparing presence in real-life against presence in VR. In order to experience presence, and in specific extended presence, in both real-life and virtual life it is required that one can distinguish between activities in the external world and activities in the internal world (Waterworth & Waterworth, 2003). The external world involves the physical world out there, and the internal world merely involves our thoughts and imaginations. Not being able to distinguish between the internal and external world leads to certain dangers. For example, in case we are physically located in a building in which the fire alarm is ringing and we react as if this external world is not really existing but only imagined, this is likely to retain us from surviving. And if we see the activities in our imagination as actually happening, such as winning the lottery, this will retain us from conducting some important activities such as working in order to earn money. In real-life, we are, in general, able to make this important distinction because of evolutionary progress (Waterworth & Waterworth, 2003). On the contrary, in VR, the distinction between what is really happening and between what is imaginary is to some extent tricked by the medium (Riva et al., 2004). In turn, making the distinction between what is really happening and between what is imagined is more complicated and vague in VR than in real-life. Not being able to make this distinction leads to diminished presence in general, and extended presence in specific (Waterworth & Waterworth, 2003).

Besides the difference regarding the identification of imagination when comparing real-life with virtual life, there is also a difference regarding its social-cultural condition. In real-life, persons are deeply involved in a fixed and well-known social-cultural community that forms an interactive bridge between objects, living beings, and situations (Riva & Mantovani, 2000). This social-cultural condition has been constituted by cultural-historical heritage, and is needed in order to make sense of the environment (Riva & Mantovani, 2000). Making sense of the environment is a prerequisite for experiencing both core- and extended presence. In VR, the social-lcultural interaction and situation is less fixed and less well-known, and requires more imagination and memory for a person to perceive oneself to be social-culturally present (Mantovani & Spagnoli, 2000). Hence, it requires more awareness for experiencing core presence and extended presence in VR compared to experiencing core presence and extended presence in real-life.

Another difference between real-life and virtual life lies in the importancy of each layer of presence. Considering the real-life situation, the importancy of each layer has been established by the evolutionary process of the self (Riva et al., 2004). In this evolutionary process, firstly the proto-self was constituted, then the core self, and finally the extended self (Damasio, 2010). These selfs were comprised in order to survive as well as to successfully deal with opportunities (Riva et al., 2004). For example, only further in the evolutionary process, imagined scenarios and future plans became more and more important for humans in order to have a succesful life in the long run. On the contrary, in the virtual life, the importancy of each layer of presence is not warranted. This might partly be attributed to the lack of the need to survive, or to successfully manage the situation, in some of the virtual situations. Moreover, this might also be ascribed to the different interests or values when being in a virtual life compared to being in real-life. Furthermore, due to the short history of virtual lives, there still might be a lack of important characteristics that are established for virtual persons in order to have optimal experiences.

6.2 Strengths and limitations

When interpreting this study and its results, some strengths and limitations must be considered. Before discussing the limitations, firstly, light will be shed on the strength of this study. The strength of this study lies in the initiation to open up the road to empirical studies that investigate the neuropsychological distinction between proto-presence, core presence and extended presence when measuring presence in VR, as well as to investigate what this theoretical distinction actually could mean for the field of practice. Therefore, this study can be considered as innovative.

On the side of the limitations, first and foremost, it should be addressed that the sample size for this study was small and therefore unlikely to possess enough power for an adequate, rather than rough, categorical principal component analysis. Another limitation involves the short duration of the chosen virtual reality application. The VR experience only lasted between 5 and 8 minutes. Because of this, time-varying qualities of presence and its layers could not be observed. Also, the short duration might have retained the participants to reach the point of fully experiencing presence, which could have been detrimental to the chance on a clear appearance of the layers of presence. A third limitation that should be addressed is that the images in the display of the virtual reality application used in this study

were a bit pixely, which could have reduced presence. Lastly, another limitation could involve the low variance in the data of some of the measurement items, such as in interview question 6, observation item 9, observation item 10. Interview question 6 contained the question: "Where you thinking about things that did not have anything to do with being on Antarctica when you were in the virtual environment of Antarctica (e.g. personal worries)?". Only one participant reported that she was thinking about other things during the VR experience. Observation item 9 consisted of: "The participant is distracted and tries to make pictures of things other than the penguins.". With regard to this item, 37 participants out of 40 showed the same behaviour. Observation item 10 involved the notion: "The participants acts upon the green checkmarks and the red crosses popped up on the camera until the goal is achieved.". With respect to this item, no variance was found. The low variance in these measurement items could have reduced the classification of behaviour and hence could have retained the classification into proto-presence, core presence and extended presence.

6.3 Recommendations for future research

For future research, it might be interesting and valuable to investigate which selfs are needed in order to survive or to successfully manage situations in virtual environments, compared to the selfs that are needed to survive in real-life. In real-life the proto-self, core self and extended self has been comprised by the need to survive. This need to survive promoted actions and intentions in different layers of presence, which in turn promoted the development of an optimal self. In order to identify an optimal virtual self, it is important to identify important states of being a virtual person in a virtual environment. In doing so, it is of great importance that the virtual environment to be used in the investigation is challenging in terms of surviving or successfully dealing with the situation, as only then actions and intentions are fully enacted and thereby making virtual behavior and virtual selfs actually visible. The identification of the selfs of a virtual person could be of great benefit as it is likely to inform about layers of presence in VR as in real-life each self of a person is related to a particular layer of presence. At the same time, it is recommended to allow for time-varying qualities of presence and its layers, as fully feeling presence is expected to require some time.

Furthermore, it might be interesting to explore the social-cultural condition of virtual environments as this condition is still not well-known, but likely to influence the level and sort of presence in virtual environments. Understanding the social-cultural condition of virtual

environments is likely to lead to more insight on the intentions, actions and interaction in virtual environments, which are expected to represent presence.

6.4 Conclusion

This study offers some valuable insights with respect to theory that points out that presence in VR should be measured by applying a neuropsychological approach that involves the distinction between proto-presence, core presence and extended presence, rather than by applying the media approach. No clear categorization into proto-presence, core presence and extended presence was empirically identified. In parallel, no persuasive support for the neuropsychological approach was found. As a result, this study encountered possible reasons for the empirical absence of the clear categorization into proto-presence, core presence and extended presence, as well as complications regarding the neuropsychological approach. All in all, this helps in understanding the neuropsychological theory from a practical point of view as well as in understanding how and in what circumstances this theory should be considered.

From a micro perspective, the results suggest that a person's general focus on environmental affordances in a VRE is intertwining the possible layers of presence and thereby retaining from a clear categorization into proto-presence, core presence and extended presence in which these layers only coexist. Secondly, the results suggest that both core presence and extended presence are dependent on conscious and interpretative effort, and thereby also on engagement related presence, which leads to overlap between these two layers. Thirdly, the results suggest that proto-presence and core presence have a shared dependence on form, which makes these two layers overlaying. Lastly, the results also suggest that the absence of the need to survive leads to minimal actions and intentions, and hence is likely to retain possible layers of presence to be maximally visible.

From a macro perspective, this study suggests that the neuropsychological three layer theory of presence is not fully and directly applicable to the measurement of presence in VR. Possible contributors to this result are some differences between real-life situations and virtual situations with regard to the dependency on form, identification of imagination, the social-cultural condition, and the importancy of the layers of presence.

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Appendices

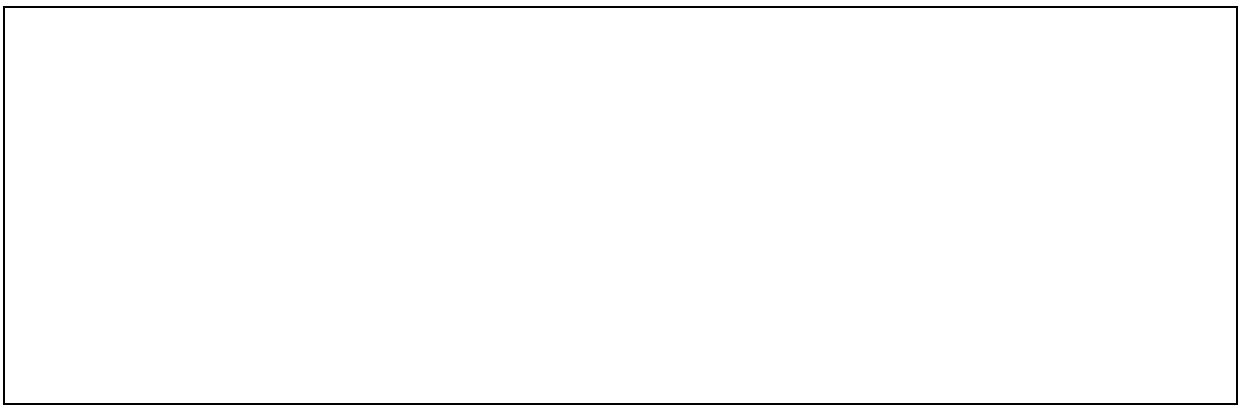
Appendix A – The behavioral observation list

Observation form Participant number _____ Date _____

Item	Options	
1. The participant turns towards the female researcher when she starts to speak.		Immediately
		After some time
		Not at all
2. The participant is moving his/her whole body when looking around.		Whole body
		Only neck/head
		Not looking around at all
3. The participants is explicitly testing whether his/her virtual legs matches the movements with his real legs.		Yes
		No
4. The participant twists his/her arms to see if he/she can see both sides of his/her arms.		Yes
		No, but looks at hands.
		No
5. The participant steps on the canvas underneath the scanner and camera, or on the scanner or camera.		Yes
		No
6. The participant succeeds in picking up the scanner and camera.		Immediately
		After some trial and error (time:)
		Not at all
7. The participant tries to walk to the penguin in order to make a proper picture.		Yes, more than 3 steps
		Yes, but less than 3 steps
		Not at all
8. The participant stops using the scanner when		Yes

he/she found the correct penguin.		No
9.The participant is distracted and tries to make pictures of things other than the penguins.		Yes
		No
10. The participants acts upon the green checkmarks and the red crosses popped up on the camera until the goal is achieved.		Yes
		No
11. The participant understands that he has to kneel down in order to make a proper picture		Yes, without any hint or instructions
		Yes, but after a first auditory hint (indirect auditory sign)
		Yes, but only after the second hint (combination of indirect auditory and visual sign)
		Yes, but only after the third hint (direct auditory hint)
		No
12. The participant tries to get in touch with the penguin that walked towards him.		Yes, he/she both tries to touch the penguin and to communicate (talking or gesturing) to the penguin.
		Yes, he/she tries to touch the penguin
		Yes, he/she is talking or gesturing to the penguin
		No
13. The participant continues talking to the researcher at the BMS lab while being in the VR environment.		Yes, at these moments:
		No, not at all.

Remarks:



Appendix B - The Igroup Presence Questionnaire

How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?

0 1 2 3 4 5 6 7

Not aware at all - Extremely aware

How real did the virtual world seem to you?

0 1 2 3 4 5 6 7

Not real at all - Completely real.

Statement: I had a sense of acting in the virtual space, rather than operating something from outside.

0 1 2 3 4 5 6 7

Fully disagree - Fully agree.

How much did your experience in the virtual environment seem consistent with your real world experience ?

0 1 2 3 4 5 6 7

Not consistent - Very consistent.

Statement: In the computer generated world I had a sense of "being there".

0 1 2 3 4 5 6 7

Not at all - Very much.

Statement: I was not aware of my real environment.

0 1 2 3 4 5 6 7

Fully disagree - Fully agree

Statement: Somehow I felt that the virtual world surrounded me.

0 1 2 3 4 5 6 7

Fully disagree - Fully agree.

Statement: I felt present in the virtual space.

0 1 2 3 4 5 6 7

Fully disagree - Fully agree.

I still paid attention to the real environment.

0 1 2 3 4 5 6 7

Fully disagree - Fully agree.

Statement: The virtual world seemed more realistic than the real world.

0 1 2 3 4 5 6 7

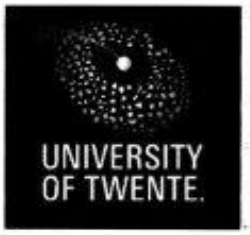
Fully disagree - Fully agree.

Statement: I was completely captivated (i.e. fascinated) by the virtual world.

0 1 2 3 4 5 6 7

Fully disagree - Fully agree

Appendix C - The informed consent



Informed consent form

This document provides you with information about the study "The measurement of presence in Virtual Reality by distinguishing between proto-presence, core presence and extended presence". Prior to participating in this study, it is important that you know about the procedure that will be used in this study and that you give your informed consent for voluntary participation. Please read this informed consent carefully.

Aim and benefit of this study

The aim of this study is to explore how the level of presence in virtual reality can be measured in a valid way. This will be of great benefit as it will lead to more informative and comparable studies about the effectiveness of presence in virtual reality when using it in the context of education. This will also inform designers of virtual reality environments on how to improve the level of presence in their virtual reality application, which potentially can make the use of virtual reality in education more effective.

Procedure

You will be asked to visit a virtual environment in which you experience the life on Antarctica. This visit will last between 5 and 10 minutes. The researcher will use an observation list to observe your behaviour in this virtual environment. For this you will be video recorded. After being in this virtual environment, you will be interviewed about your experiences. Lastly, you will be asked to fill out a short questionnaire so that the new developed instruments for this study can be compared with an existing instrument.

Risks

This study does not imply any risks or detrimental side effects.

Duration

This study will last between 20 and 30 minutes.

Participants

All participants have a minimal age of 18.

Voluntary participation

Your participation is absolutely voluntary. You can decide not to participate without giving any reasons, and it is also possible for you to end your participation at any time. You can recall from your consent to use your experimental data within 24 hours after participating in this study. This will not have any consequences.

1

Confidentiality

All personal information about you will not be shared outside the research team. The video recordings will only be used for scientific analysis purposes, and will only be used for public presentations after asking for your explicit consent. The data that will be gathered for this study will be used for writing scientific publications. Only the researcher will know about your identity and will retain this information from anybody else. This guarantees your anonymity and makes sure that the information in the publications cannot be traced back to you.

Additional information

In case you would like to have more information about this study, do not hesitate to ask Judith Frissen (e-mail: j.v.h.frissen@student.utwente.nl).

Certificate of consent:

I, (name) _____ , have read and understood this consent completely and consent to voluntary participate in this study.

I also CONSENT/ DO NOT CONSENT (encircle your preference) with the video recordings being used for public presentation purposes.

Participant's signature: _____ Date: _____

Appendix D – Instructions and actions from the researcher during the experiment

Actions and instructions during this study:

- The researcher fills in the participant number on the to be used observation form -

Researcher: "Thank you for being here. Before we start, I first would like to provide you with the informed consent of this study in which you will be given all the crucial information about participating in this study."

- The participant will read and sign the informed consent. -

Researcher: "Next, I would like to ask you to take place in the virtual environment. For this, I will provide you with a head mounted headset and hand controllers. When you put this equipment on, a menu will be appearing in front of you. You can use your right hand controller to select the environment of Antarctica by pointing at it while pressing any button on the hand controller. Then your experience on Antarctica will start. When it is over, the VR application will bring you back to the same menu as the one you saw in the beginning. When this happens I will give you a sign that you can put your equipment off. Are you ready? Then you can put your equipment on and start."

- The participants visits the virtual environment. -
- The researcher makes video-recordings of the participation -
- The researcher observes the participant by use of the observation form -

Researcher: "Now, I would like to conduct a semi-structured interview with you in order to gain insight in how you experienced being in this virtual environment."

- The researcher will conduct the semi-structured interview and will make notes of the answers in the digital interview form -

Researcher: "Lastly, I would like to ask you to fill in the Igroup Presence Questionnaire, so that the validity of the instruments developed for this study can be tested. This questionnaire consists of 11 short questions in which you will be asked to indicate to which extent you agree with a certain statement about your experiences in the virtual environment."

- The participant will be given a laptop so that he/she can fill out the Igroup Presence Questionnaire individually -

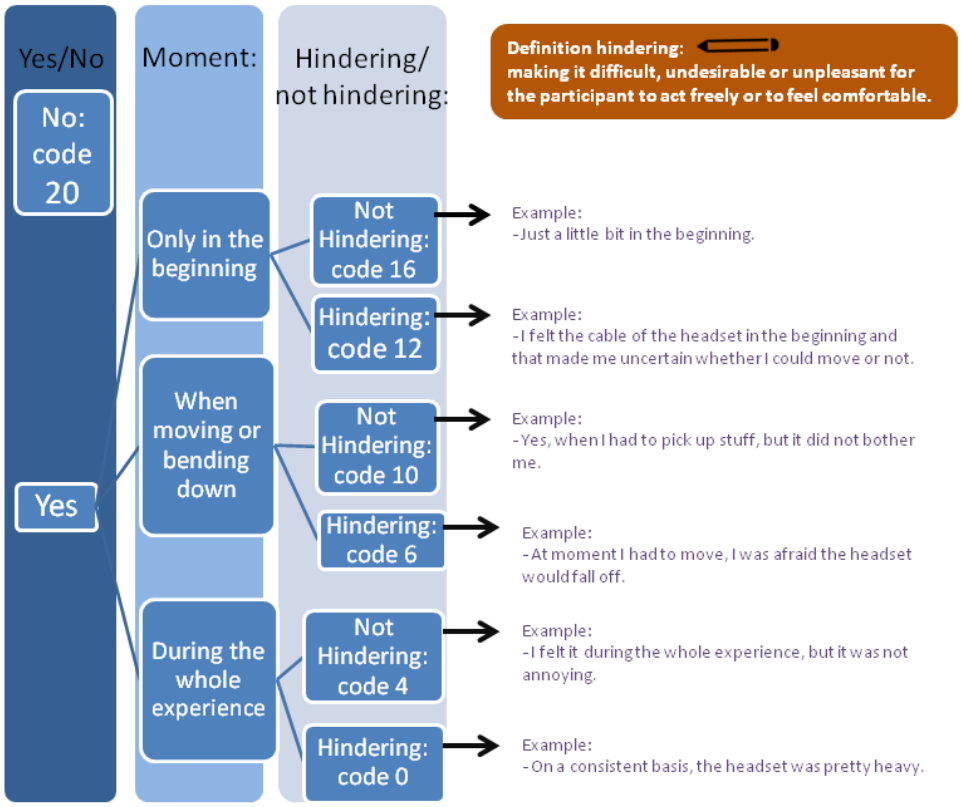
Researcher: "Thank you for your time!"

Appendix E – Coding scheme

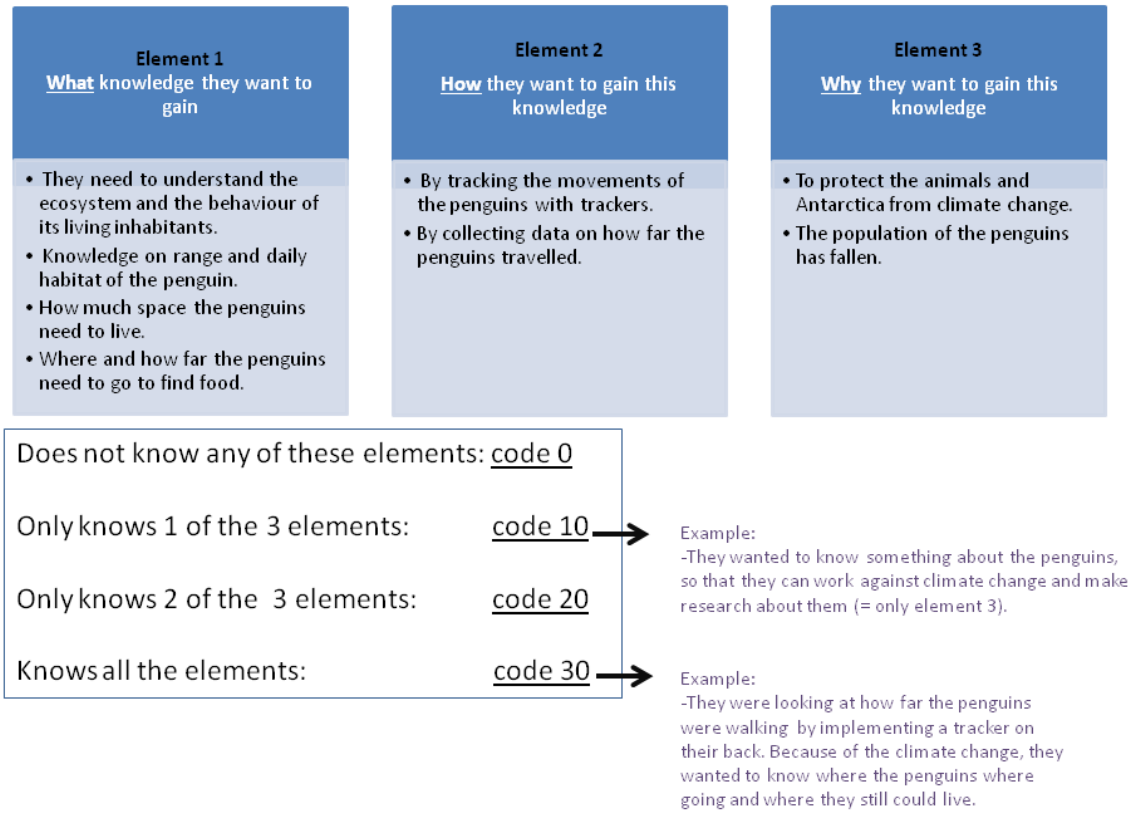
Coding scheme semi-structured interviews

Q1 - Did you hear sounds from OUTSIDE the virtual reality application when you were on Antarctica? (2 codes)

Q2 - Did you still feel the weight of the headset on your head when you were on Antarctica? (7 codes)



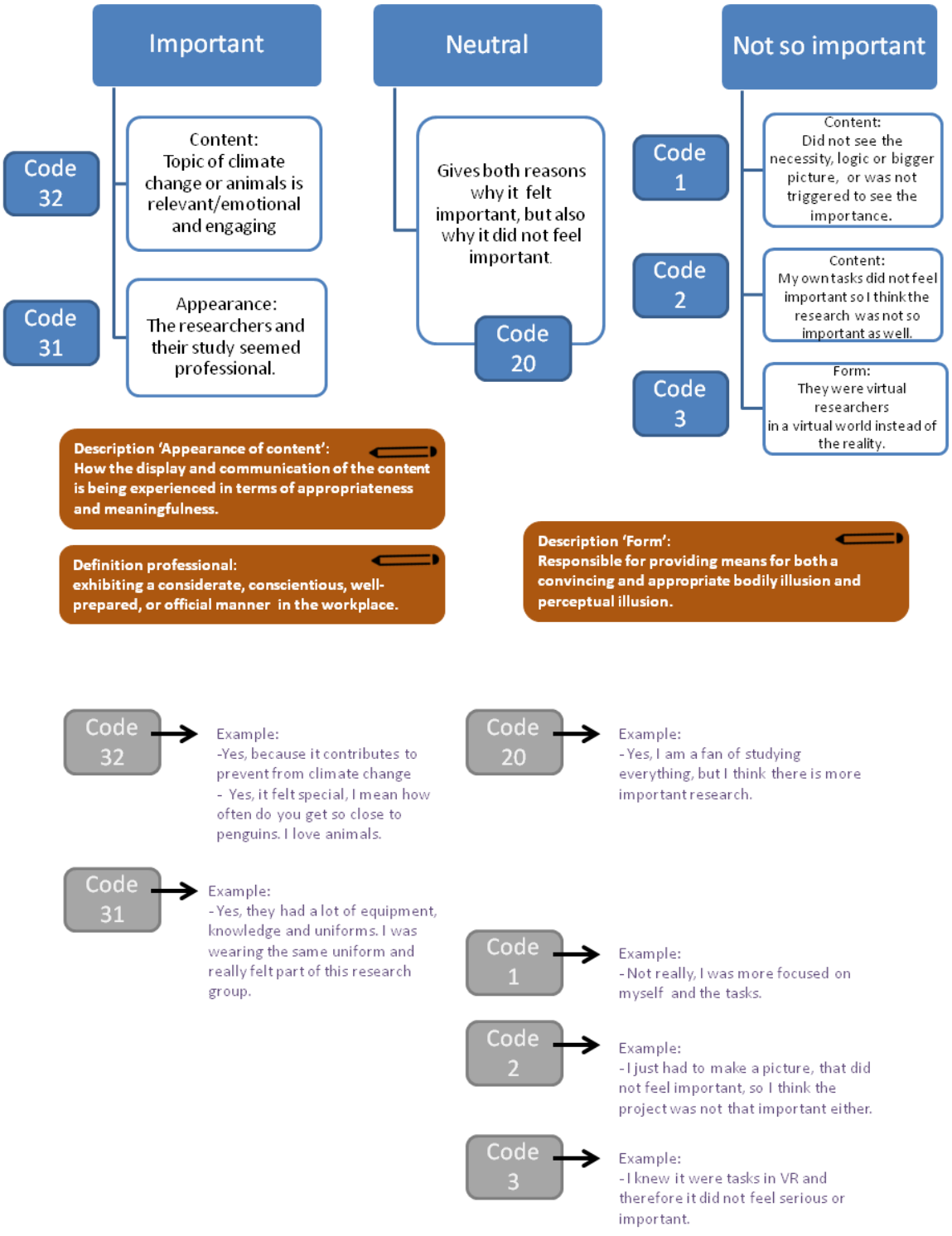
Q3 - Could you tell me what the Antarctic researchers were investigating on Antarctica? (4 codes)



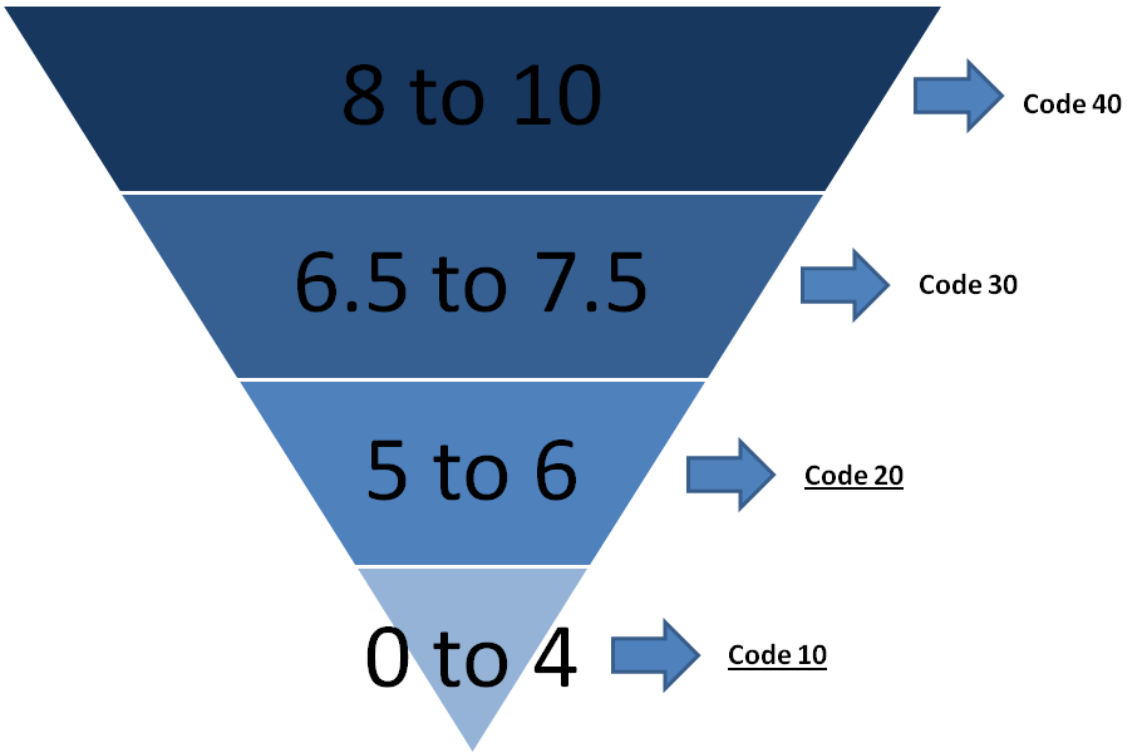
See next page.

Q4 - Do you view the work of the Antarctic researchers you met on Antarctica as important? Why? Could you indicate on a scale from 0 to 10?

Q4 A. Rationalization: Do you view the work of the Antarctic researchers you met on Antarctica as important? Please explain (6 codes)



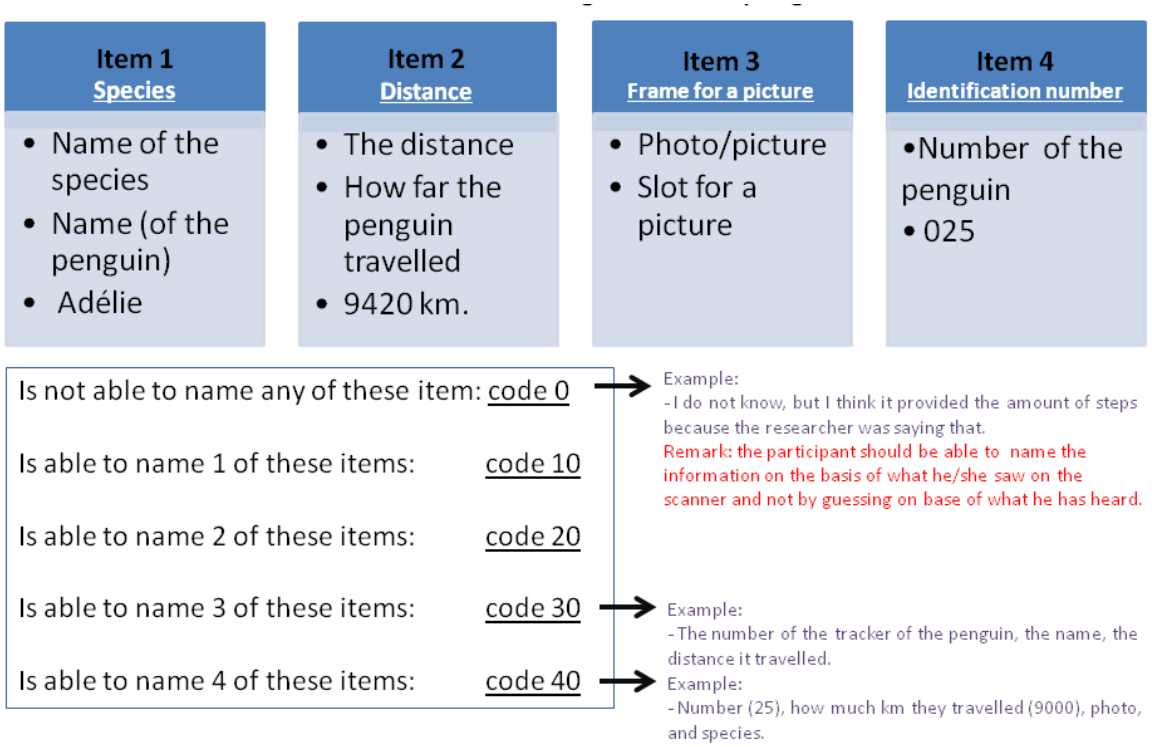
Q4 B. – Intuition: Could you indicate on a scale from 0 to 10 how important it felt? (4 codes)



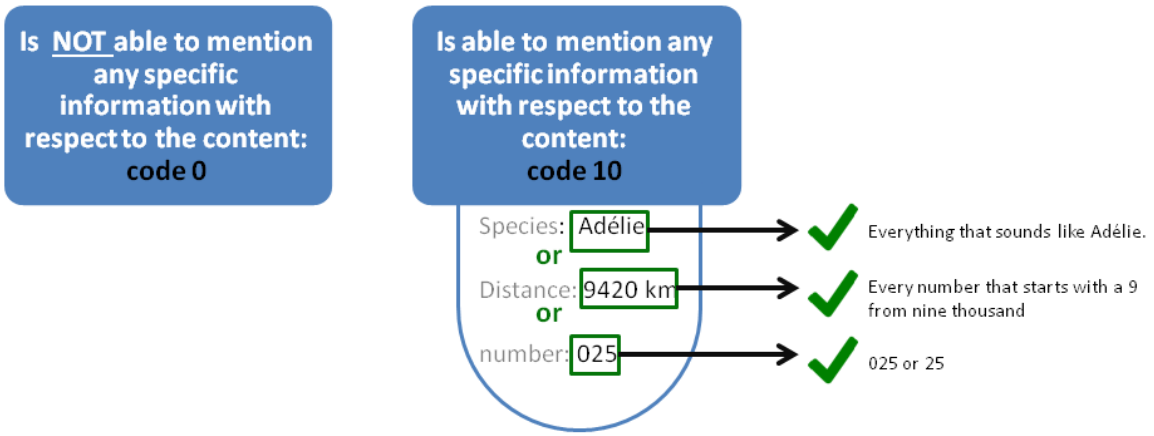
See next page.

Q5 - Do you know what information was shown on the scanner after you scanned the correct penguin?

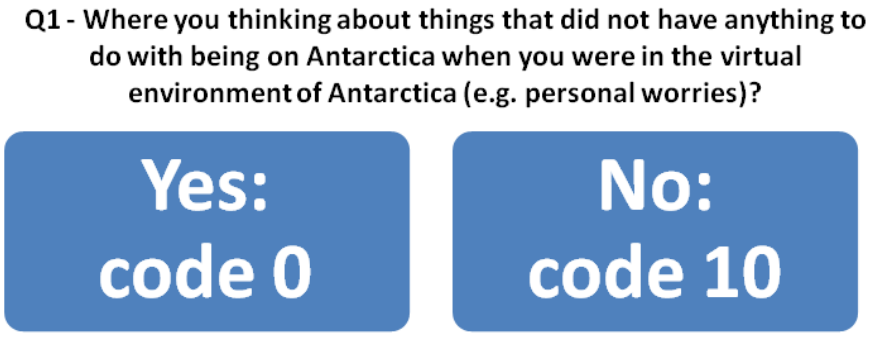
Q5 A. The extent to which the participant knows what kind of information was shown on the scanner after scanning the correct penguin. (5 codes)



Q5 B. Determining whether the participant is able to name any specific information with respect to the content. (2 codes)

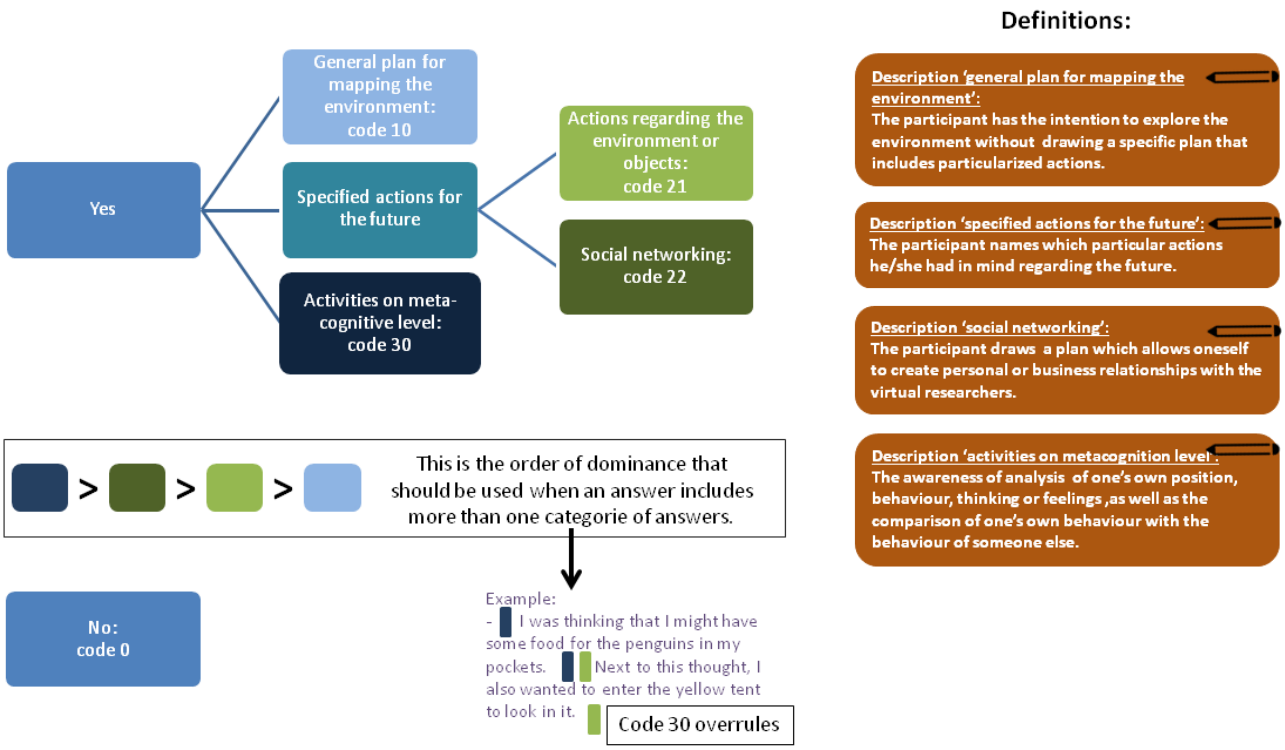


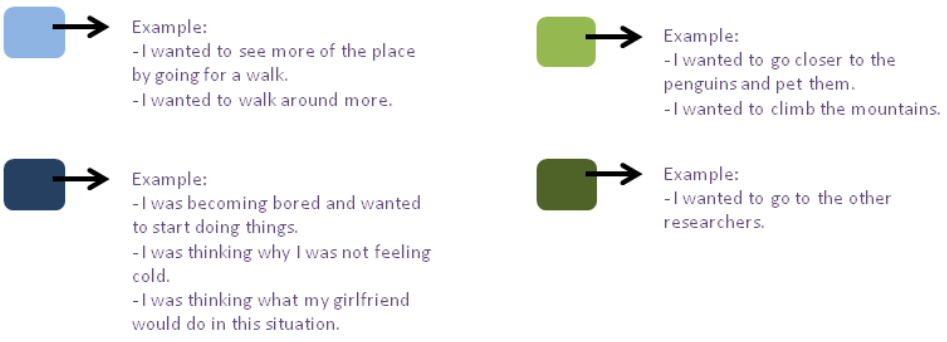
Q6 - Where you thinking about things that did not have anything to do with being on Antarctica when you were in the virtual environment of Antarctica (e.g. personal worries). (2 codes)



See next page.

Q7 - Where you thinking about what you would do there when the Antarctic researchers would not have given you these specific tasks with the scanner and camera? (5 codes)





Q8 - Was it clear to you what you had to do at each moment on Antarctica? Both what your tasks were, and also how to achieve them? (4 codes)

Identification of the task:

When the respondent expresses any haziness regarding the identification of tasks, then use **code 0.** Even though when the respondent also expresses any haziness regarding how to achieve certain tasks.

Haziness regarding the tasks:
- When the participant did not know when to use the scanner and when to use the camera
- When the participant found it hard to identify what the camera was and what the scanner was
- When the participant was doubting whether he/she had missed a given task or when he/she could not always distinguish between the provision of just information and the provision of a task

The achievement of the task:

When the respondent expresses any haziness regarding how to achieve the task, then use code 5 or 10. Use **code 5** when he/she expresses technical inaudibility. Use **code 10** when he/she expresses vagueness regarding how to perform.

Technical inaudibility:
- Uncertainty regarding which buttons to press
- Uncertainty regarding how the scanner works.

Vagueness regarding how to perform:
- Vagueness regarding how to take a proper picture (e.g. how to draw/get the penguin closer).

Otherwise: **code 20**

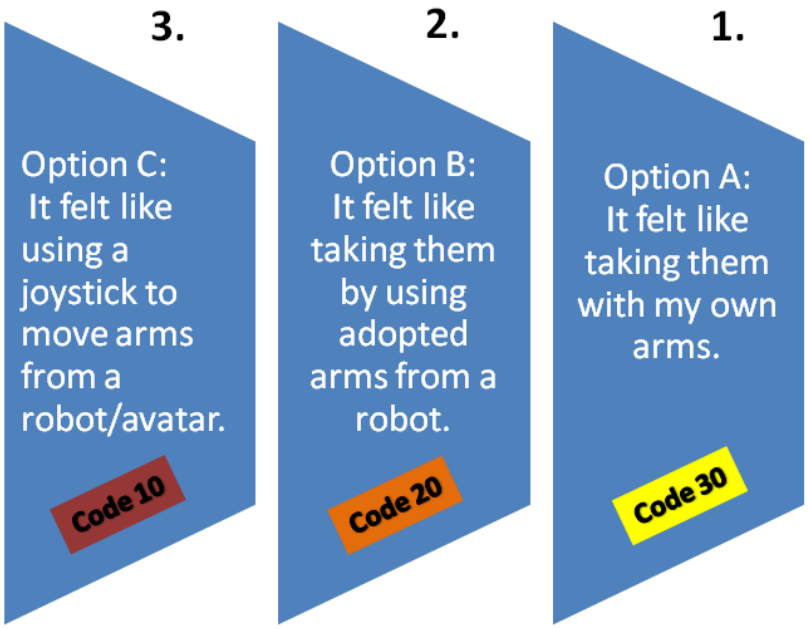
code 0 →
Example:
- On a certain moment, I did not know anymore which of the two instruments was the camera and which was the scanner, because I had to less insight in what I was supposed to do.

code 5 →
Example:
- No, the scanner instructions should be more clear. To someone who is not used to such kind of handcontroller, you use the wrong button. It was not clear for how long to press the trigger.

code 10 →
Example:
- Almost, I was a bit confused how to take the picture.

code 20 →
Example:
- Yes, but at first when I had to take a picture I thought I can not just walk there because I would make the penguin scared. Then I thought how would I do this with my dog?

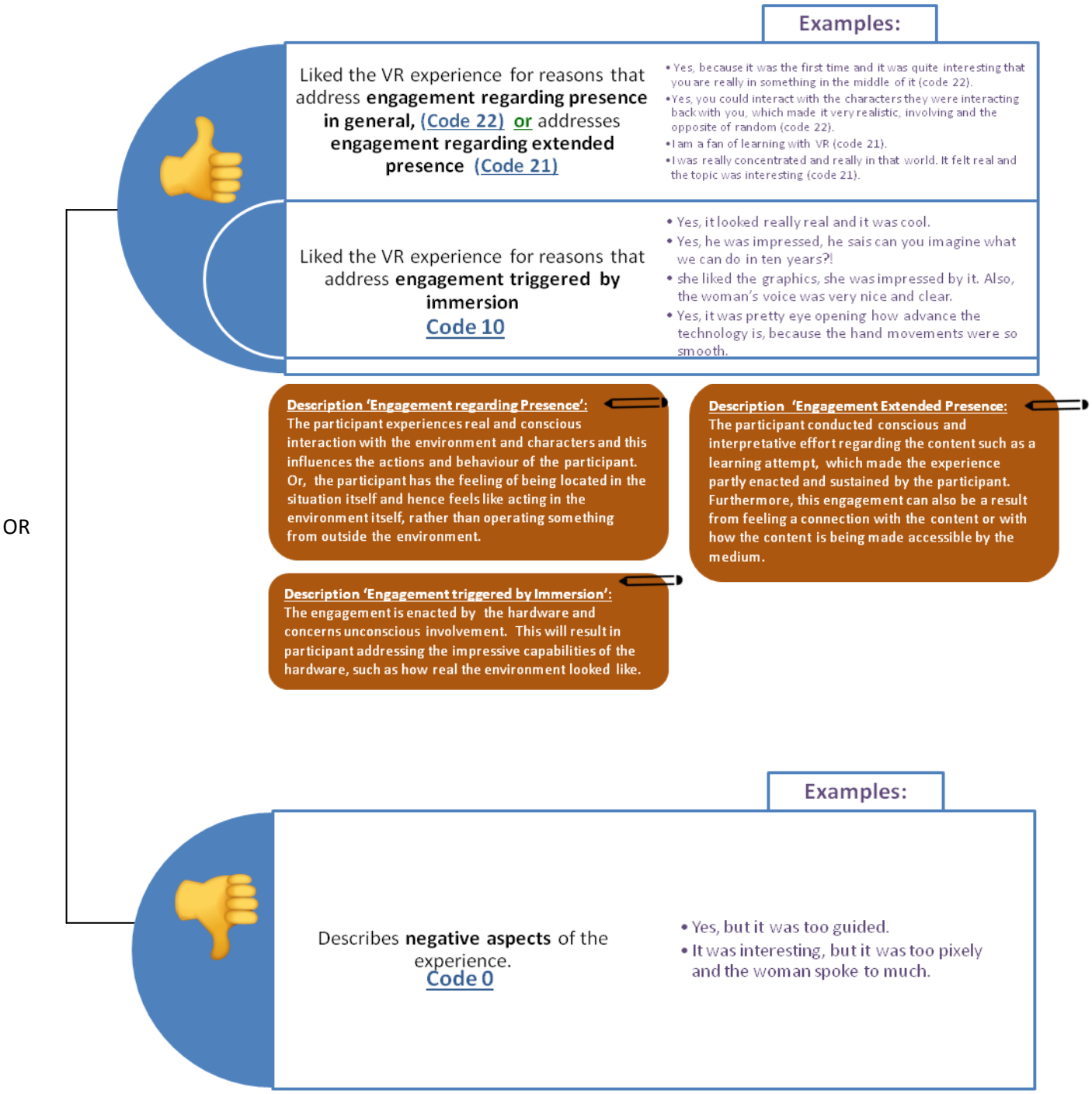
Q9 - How did you feel when you were picking up the scanner and camera from the ground (e.g. Did you feel like you were taking the scanner and camera with your own arms, like you were taking the scanner and camera by using adopted arms from a robot, or like you were using a joystick to move the arms of a robot?). (3 codes)



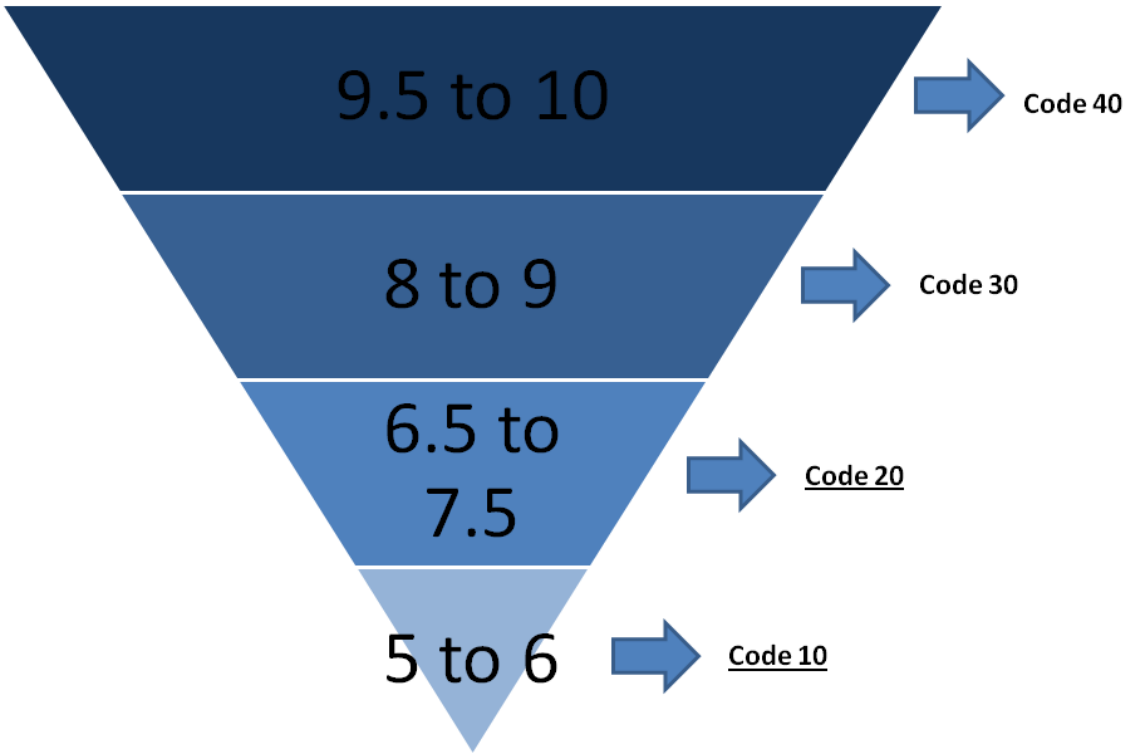
See next page.

Q10. - Did you enjoy having this VR experience? Could you indicate on a scale from 0 to 10?

Q10 A. Did you enjoy having this VR experience? Please clarify. (3 codes)



Q10 B. Could you indicate your enjoyment on a scale from 0 to 10? (4 codes)



The end.