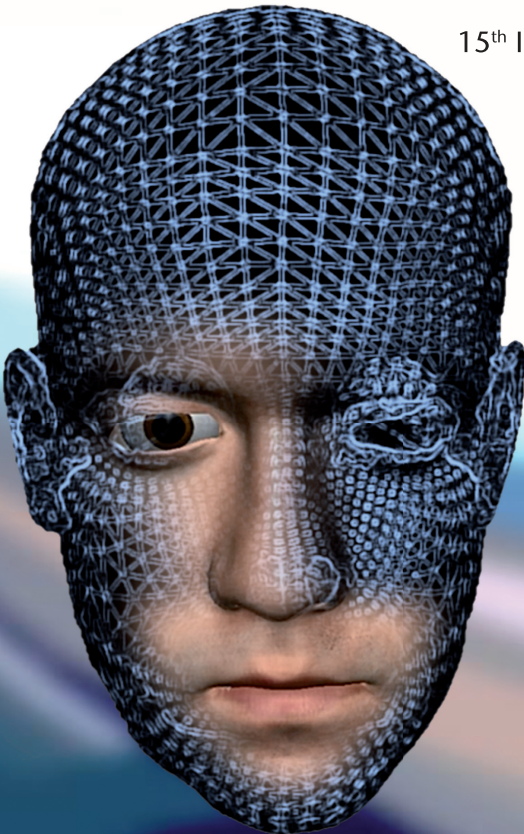


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(Eds.)

# Challenging Presence

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# Effects of Age on the Subjective Presence Experience in Virtual Reality

Silvia Erika Kober<sup>1</sup>

**Abstract.** The subjective “sense of being there”, otherwise known as presence experience in virtual reality (VR), plays an important role in VR research. However, inter-individual differences in the presence experience are not well examined yet. The aim of the present study was to investigate the effects of age on the subjective presence experience in VR. Therefore, we combined the results of four different VR studies, in which the presence experience of young and older people was assessed while interacting in immersive virtual environments. Age was negatively correlated with the presence experience in VR in young (18-28 years) as well as in older (45-80 years) participants indicating that there is a strong relationship between inter-individual difference such as age and presence experience in VR. Hence, as age increases, the intensity of the “sense of being” in VR decreases. The effects of age on the presence experience in VR might be caused by various factors such as personality, immersive tendencies, experience with computer technique, computer anxiety, or physiological and cognitive declines with age. Furthermore, the relationship between age and presence disappeared when the setting of the measurement changed. No correlation between age and presence was found when the participants’ brain activation was assessed using neurophysiological methods while interacting in VR. Conducting additional neurophysiological measurements, which are unrelated to the VR scenario, might hamper deep immersion in VR. Consequently, the real world around the VR user cannot be neglected easily any more.

**Keywords.** Age; Presence; Inter-individual differences; Neurophysiological methods; Virtual reality

## Introduction

Virtual reality (VR) turned out to be a valuable tool for educational and medical purposes such as training and rehabilitation. The success of VR applications is thought to be associated with the subjective presence experience, also known as the “sense of being there”, since presence is considered as the propensity of VR users to respond to virtually generated sensory data as if they were real (Slater et al., 2009). Such natural behavior in VR may foster the transfer of knowledge acquired in VR to corresponding real world behavior (Slater et al., 1996). Nevertheless, approaches to study inter-individual differences in presence experience such as the effects of age on presence are limited (Kober & Neuper, 2013).

VR researchers agree that presence is influenced by technology-related (external) and user-related (internal) factors (IJsselstein & Riva, 2003). User-related or internal factors refer to inter-individual differences of the

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VR users such as age, gender, personality, or experience of playing computer games and how individual experiences in virtual environments are processed internally (Usuh & Slater, 1995). Nevertheless, systematic approaches to study user-related factors, which may correlate with presence, are limited (Kober & Neuper, 2013). Especially, effects of age on subjective VR experience are scarcely investigated. The majority of VR research focuses on younger users. However, since the number of studies using VR as rehabilitation tool for mainly elderly people is rising (Brooks & Rose, 2003; Holden, 2005; Kober et al., 2013), it is important to investigate the relationship between age and presence and how elderly people engage with virtual environments (Siriaraya & Siang Ang, 2012). Up to date only a few studies investigated this relationship and reported contrary results (van Schaik et al., 2004; Stavropoulos et al., 2013; Ling et al., 2013; Schuemie et al., 2005; Siriaraya & Siang Ang, 2012). For instance, Van Schaik et al. (2004) found a negative correlation between the subjective presence experience and age, whereas Stavropoulos et al. (2013) found a positive relationship between these variables in healthy young people. Siriaraya et al. (2012) found no relationship between age and presence experience in VR. Hence, the effects of age on the subjective “sense of being there” in VR remains unclear.

Technology-related or external factors include for instance screen size, stereoscopy, design factors, display or VR devices, which have a strong impact on the presence experience in VR (Slater et al., 2009). External factors also include the setting of the measurement. For instance, the number of studies examining neurophysiological underpinnings of VR experience is rising. In these neurophysiological studies, the VR users are wearing for example electrode caps on the head to measure the electrical activity of the brain (electroencephalogram, EEG) (Baumgartner et al., 2006; Kober et al., 2012) or they are lying in a narrow magnetic resonance (MR) scanner to measure hemodynamic brain responses while interacting in VR (Jäncke et al., 2009). These unnatural circumstances of the setting of neurophysiological measurements can influence the presence experience in VR, too. The comfort for the VR users might be negatively affected due to the neurophysiological measurement, which may hamper deep immersion in VR.

In the present work we report the results of four different VR studies, in which the presence experience of young and older people was assessed during interacting in VR. Furthermore, in two of these four studies brain correlates of VR experience were assessed using different neurophysiological methods. The aim of the present work is twofold: Firstly, we want to examine whether there is a relationship between age of the VR user and subjective presence experience in VR. Secondly, we investigate whether external factors such as neurophysiological measurements influence the relationship between presence experience in VR and inter-individual factors such as age.

## Methods

In Table 1 the methodical details of the four different studies reported in the present work are summarized.

### *Participants*

Different samples were examined in the four empirical studies investigating presence experience in VR. A description of each of the four samples is shown in Table 1. Healthy young adults participated in study 1, 2, and 3. The age of these young participants ranged from 18 to 40 years. In study 4, healthy middle-aged and elderly as well as aged-matched patients with brain lesions participated. A comprehensive description of the neurologic patients can be found in Kober et al. (2013). The age of these middle-aged and elderly participants ranged from 45 to 80 years (Roebuck, 1979). In study 2 and 3, the participants’ brain activation was assessed using different neurophysiological methods (electroencephalogram EEG, near-infrared spectroscopy NIRS) during navigating through VR. No neurophysiological measurements were performed in study 1 and study 4 while interacting in VR.

**Table 1.** Methodical details of the four studies on presence in VR summarized in the present work.

	Age	Sex	State of health	VE	VR technology	Presence measures	Neuro-physiological measurement
Study 1 ( <i>N</i> = 20)	18-28 years	11 females, 9 males	Healthy	Virtual city	Single-Wall VR system (3D)	SFQ	None
Study 2 ( <i>N</i> = 45)	18-33 years	32 females, 13 males	Healthy	Virtual city	Single-Wall VR system (3D)	Rating scale, SUS, PQ, SFQ	EEG
Study 3 ( <i>N</i> = 29)	19-40 years	14 females, 15 males	Healthy	Virtual maze	Single-Wall VR system (3D) ( <i>N</i> = 14) & Desktop system (2D) ( <i>N</i> = 15)	Rating scale, SUS, PQ	EEG & NIRS
Study 4 ( <i>N</i> = 21)	45-80 years	12 females, 9 males	Healthy ( <i>N</i> = 10) & neurologic patients ( <i>N</i> = 11)	Virtual city	Single-Wall VR system (2D)	Rating scale	None

In the studies examining healthy young adults (study 1, 2, and 3), the participants' experience of playing computer games was assessed, too. Therefore, participants rated how often they normally play computer games on a 5-point rating scale ranging from 1 (daily) to 5 (never). The samples of the different studies did not differ in their experience of playing computer games ( $\chi^2(8) = 14.57, ns$ ).

#### *Virtual environments*

Two different virtual environments were used to assess presence in VR (Figure 1). In study 1, 2, and 4, participants navigated through a virtual city. This virtual city was a virtual model of a part of the city of Graz, Austria. In study 3, participants navigated through a virtual maze, which consisted of brick walls, a similarly colored stone floor and a blue sky. Additionally, spatial cues, so called landmarks (e.g. a table, a vase, or colored balls) were placed in the maze, which could be used as navigational aids. In all studies, participants performed a navigation task in the virtual environment for approximately 30 minutes, where they had to find the shortest ways from a starting point to an endpoint in the VR after a learning phase. Participants navigated through the VR in a ground-level, first-person view by using a joystick or the computer keyboard.

Three different VR systems were used in the presented studies. In a highly immersive Single-Wall VR system (3D), a virtual reality projector Cube3D<sup>2</sup> (Digital Image, Overath, Germany) projected the virtual environments on a 2x2 meter projection screen. Participants wore shutter glasses that were used as stereoscopic imaging device (study 1, 2, and 3). In a less immersive Single-Wall VR system (2D), a conventional projector was used presenting the VR in a monoscopic view on a large projection wall (study 4). The third VR system was a Desktop system (2D), where participants viewed the VR on a conventional 21-inch computer screen in a monoscopic view (study 3).

#### *Presence Measures*

To assess the subjective presence experience in VR, different presence measures were used: Participants rated the intensity of their sense of being in the VR on a conventional rating scale from 0 to 4, where 0 represented "not at all" and 4 represented "very strong". In study 4, the rating scale ranged from 0 to 10. Beside the rating scale, participants filled in post-immersive pre-



**Figure 1.** Sample views of the virtual environments. Left panel: Virtual maze. Right panel: Virtual city.

sence questionnaires. The Short Feedback Questionnaire (SFQ) (Kizony et al., 2006) is a short post-immersive presence questionnaire containing six questions related to the feeling of presence, e.g. the feeling of enjoyment, success, or control. One example of a SFQ item is “*Did the environment seem realistic to you?*”. The Presence Questionnaire (PQ) (Witmer & Singer, 1998) contains 19 items, assessing for instance the perceived control of events in VR, naturalness of VR interaction, or possible distractions of VR experience. One example of a PQ item is “*How much did your experiences in the virtual environment seem consistent with your real-world experiences?*” (scale naturalness). The SUS (Slater-Usch-Steed questionnaire by Usch et al., 2000) contains 15 items, 5 items are related to presence assessing the sense of being in the VR, the extent to which the VR becomes the dominant reality, and the extent to which the VR is remembered as a place. One example of a SUS item is “*Please rate your sense of being in the virtual environment on the following scale from 1 to 7, where 7 represents your normal experience of being in a place*”. For better comparability between the different studies and to combine the various presence measures assessed in study 2 and study 3, Z-scores of each presence measure (rating scale, SFQ, PQ, SUS) were calculated. For study 2 and study 3, a total presence score was calculated by averaging the Z-scores of the different presence tests (Kober & Neuper, 2013).

#### *Neurophysiological measurement*

Cortical correlates of human experiences in VR were examined using multi-channel electroencephalography (EEG) and near-infrared spectroscopy (NIRS). The electroencephalogram (also EEG) measures the electrical activity of the brain along the scalp, which consists of ionic currents generated by biochemical sources at the cellular level (Niedermeyer & Lopes da Silva, 2005). NIRS is a relatively new non-invasive optical neuroimaging technique measuring relative concentration changes of oxygen-rich and oxygen-poor blood on the surface of the brain (Villringer & Chance, 1997). Generally, in neurophysiological studies factors such as measurement preparation or comfort for participants are important points. The montage and preparation of EEG electrodes is quite tedious. Abrasive gel is needed to get a good contact between the participant’s head and the electrode. This gel can lead to skin irritations. Compared to EEG, the montage of the NIRS optodes is rather fast. However, depending on the NIRS system side effects such as headache or nausea may arise.

## **Results**

Correlation analyses were applied to examine if there is a relationship between age of the VR user and the subjective presence experience. Therefore, we correlated the age of the participants with

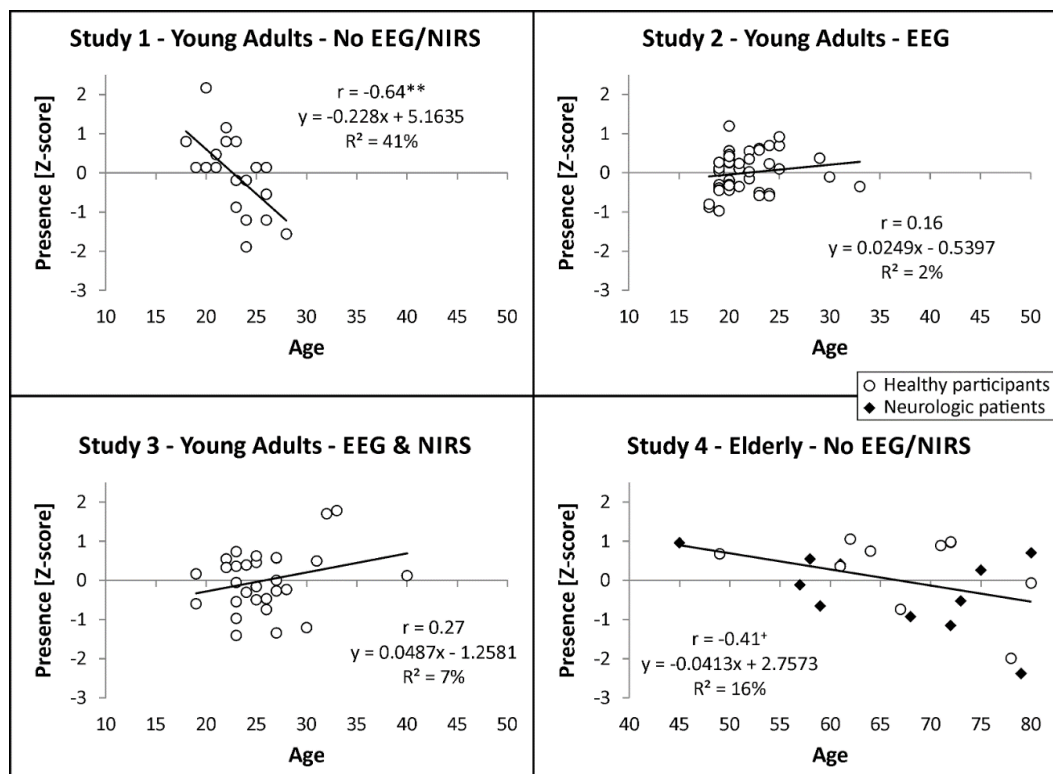


the z-transformed total presence score, separately for each of the four empirical studies. In Figure 2 the results of these correlation analyses are depicted, separately for each study. In study 1, age was highly negatively correlated with the subjective presence experience ( $r = -0.64$ ,  $p < 0.01$ ). Hence, the intensity of the presence experience in VR decreased with age in this healthy young population. Additional regression analysis (predictor variable = age; dependent variable = z-transformed total presence score) emphasized the results of the correlation analysis. The regression model for the total presence score of study 1 was significant ( $F(1, 18) = 12.60$ ,  $p < 0.01$ ). The age of the healthy young VR users explained 41% of variance of the presence experience.

In sharp contrast, no significant relationship between age and presence experience could be found in study 2 and study 3, in which additional neurophysiological measurements were performed while interacting in VR. Although not significant, healthy young adults that participated in study 2 and 3 showed slightly positive correlations between age and presence (study 2:  $r = 0.16$ ,  $ns$ ; study 3:  $r = 0.27$ ,  $ns$ ). Also, the regressions analyses did not reveal significant results (study 2:  $F(1, 43) = 1.09$ ,  $ns$ ; study 3:  $F(1, 27) = 2.15$ ,  $ns$ ).

The results of study 4 support the findings of study 1. Healthy middle-aged and elderly as well as neurologic patients of the same age showed a negative correlation between the subjective presence rating in VR and age, which was by trend significant ( $r = -0.41$ ,  $p = 0.06$ ). The regression model for the z-transformed presence rating of study 4 was significant by trend too ( $F(1, 19) = 3.79$ ,  $p = 0.06$ ). The age of the older VR users explained 16% of variance of the presence experience.

All results of the correlation and regression analyses were comparable between male and female participants and the results were unrelated to the young participants' experience of playing computer games.



**Figure 2.** Results of the correlation and regression analyses, presented separately for the four different studies on presence in VR. Significant results are marked with asterisks ( $^{+}p < 0.10$ ,  $^{**}p < 0.01$ ).

## Discussion

In the present work we investigated the effects of age on the presence experience in VR. Therefore, we analyzed the data of four different VR studies in which the “sense of being there” was assessed in younger (18-40 years) and older (45-80 years) adults. Furthermore, we investigated whether external factors, which are unrelated to the VR scenario such as neurophysiological measurements, may influence the relationship between presence in VR and age. In the following the results of the present work are discussed in more detail.

In study 1 and 4, in which no neurophysiological measurements were performed, we found a negative correlation between the subjective presence experience and age, which was supported by the correlation and regression analyzes. Furthermore, age turned out to be a valid predictor of presence, explaining 41% of variance of the presence experience in young and 16% of variance of the presence experience in older VR users. These results were independent of the used VR technique (2D vs. 3D), gender, the used presence measure, and the state of health, which varied between study 1 and 4. Van Schaik et al. (2004) also found a negative correlation between age and presence. They examined the relationship between spatial presence and age in healthy young and middle-aged adults with an age range of 16 to 50 years (van Schaik et al., 2004). In the present work, we found a negative relationship between presence and age in healthy young (18-28 years) as well as in middle-aged and elderly adults (45-80 years). Hence, we could show that the relationship between inter-individual differences and the subjective presence experience exists in both healthy younger adults that are familiar with computer technique as well as in middle-aged and elderly people with hardly any computer experience.

The experience with computer technique might influence the relationship between age and presence experience. Van Schaik et al. (2004) mention that a lack of experience with computer games, which should be stronger in older people, may have caused a difficulty in navigation and thereby lower presence experience leading to a negative correlation between age and presence. This might explain the negative correlation between age and presence in middle-aged and elderly people between 45 and 80 years who had hardly any prior experience with computer technique (study 4). However, we did not find any relationship between the subjective presence experience and the participants’ experience with computer games in the younger samples (study 1, 2, and 3). In contrast to the results of van Schaik et al. (2004), we did not find a negative relationship between age and the experience with playing computer games in healthy young adults. The variability in the experience with playing computer games in the present younger samples was rather low. All young participants had prior experience with playing computer games. Hence, the negative relationship between presence and age in younger adults might not be caused by prior experience with computer games.

There is evidence that older adults take more time to learn how to use a computer (Wagner et al., 2010). Age is influential in determining how much difficulty a person will experience in learning a new system, such as VR. The higher the complexity of a system, the more influential are the effects of age, especially when information from different sensory channels has to be integrated. Furthermore, deficits in perception and cognition, which are often experienced by elderly people, may lead to a reduction in the information perceived from virtual environment consequently reducing engagement in VR (Stanney et al., 1998). Studies on people above 40 years old provide evidence that as age increases, attitudes toward computer technique tend to become more negative and increasing age is associated with increased computer anxiety. Older people have more negative emotional reactions to making computer errors (Wagner et al., 2010). This might also explain the negative relationship between age and presence experience in the older sample of the present work ranging from 45 to 80 years but not the negative relationship between presence and age in the healthy young sample with an age range of 18 to 28 years. Recent VR studies showed that personality variables such as absorption or immersive tendencies are positively correlated with the presence experience in VR (Kober & Neuper, 2013).



Probably, it is easier for younger people at the beginning of their twenties to become fully involved or immersed in events such as virtual scenarios and to focus attention on VR while blanking out the real world, which may foster presence experience, compared to people at the end of their twenties. Supporting this assumption there is evidence that the personality variable absorption is negatively correlated with age (Hölzel & Ott, 2006). Hence, younger people are more likely to fully engage one's representational resources and become totally immersed in events or objects than older people. Adults aged around 30 years with less computer experience than younger people aged around 18 years are probably more skeptical toward such immersive experiences, which might hamper deep immersion and consequently the presence experience in VR. Further studies are needed to address the relationship between age, presence, and personality variables in more detail.

The second aim of the present work was to investigate whether external factors such as neurophysiological measurements may affect the effects of age on presence experience in VR. The relationship between age and presence was influenced by external circumstances of the setting of the measurement, which were unrelated to the VR task. In study 2 and 3, in which the participants' brain activation was assessed while interacting in VR using EEG and NIRS, we found no relationship between presence and age. Generally, a high presence experience in VR is associated with an experience of feeling deeply engaged with the virtual world, while "forgetting" the real world (Qin et al., 2009). Probably, neurophysiological measurements hamper this deep engagement in VR, since the EEG electrodes or NIRS optodes, which are mounted on the head of the VR user while interacting in VR, always remind the VR user of the real world. Hence, this strong impact of external factors such as the neurophysiological measurements on the presence experience may interfere with or overlay the influence of internal factors such as age on presence.

Although subjective self-report questionnaires are the most common technique to measure presence, they are associated with some disadvantages. For instance, the term "presence" is not well known to the general public. Hence, for some VR users it might be difficult to quantify and rate this subjective experience and consequently they have to guess (Kober & Neuper, 2012). Therefore, there are attempts to measure presence more objectively via physiological measures such as heart rate, electrodermal activity or brain responses (Slater et al., 2009; Kober & Neuper, 2012). The rationale behind this objective presence measure is that if the physiological response to specific events in real and virtual situations is comparable, e.g. in stress-inducing situations, then this might be a sign of presence (Slater et al., 2009). However, based on our findings one has to consider that conducting (neuro-) physiological measurements during VR interaction may influence the VR experience.

### **Limitations and Conclusion**

In the present report, we combined the results of four different VR studies examining different samples and using different VR systems and presence questionnaires. Hence, the different VR systems used may have challenged different navigational abilities as well as resulted in different usability and ease of use ratings. The latter is known to be closely related to age (i.e. elderly people have more difficulty of adopting new systems). Therefore, the heterogeneity of the reported studies is a limitation of the present report.

As age increases, the presence experience in VR decreases in healthy young as well as in older people. The negative relationship between age and presence in the middle-aged and elderly might be explained by various factors such as experience with computer technique, computer anxiety, attitudes toward computer technique or physiological and cognitive declines with age. The reasons for the negative relationship between age and presence in younger adults between 18 and 28 years old are not that obvious. Future studies are needed to investigate that in more detail. Assessing more user-related factors such as personality, education, immersive tendencies or more detailed questions about computer experience such as the type of favorite computer games, aver-

age duration of playing computer games, internet use, etc. might shed light on the reasons for the negative relationship between age and presence experience in VR in younger people.

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