Measurement of Presence by a Presence Counter Based on Breaks in Presence

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Abstract

The paper is concerned with methods of measuring presence. The physiological and behaviour methods are situation-specific whereas subjective method is used after virtual session. In this paper we focus on the method that evaluates the presence counter based on breaks in presence (BiP). The advantage of this method is its implementation during the virtual session, during the virtual experience.

Within the experiment, 22 participants walked around the virtual Asian park and searched for virtual vases. They gave signals when BiPs occurred. The presence counter can be calculated based on this data. To validate this approach the participant were asked to answer ITC-Sense of Presence Inventory (ITC-SOPI) after the virtual session.

Our approach of computing the presence counter involves the Markov chain that is a simplest model of stochastic process.

Presence counter based on BiP and the Markov chain was proposed by Slater and Steed. They consider the discrete time model. In the paper we revisit this approach and, additionally, develop the continuous time Markov chain based method of presence counter. The calculation of the correlation between the presence counters based on BiP and results of ITC-SOPI showes that the counters relied on the continuous time Markov chain are most sensitive. This paper shows that a BIP-based presence counter can be used as an effective presence measure.

Keywords

Virtual reality, presence, mediated presence, presence measurement, breaks in presence, Markov chains, presence counter

1. Introduction

The virtual reality is a special technology that makes it possible to create an interactive three-dimensional environment. The presence is the main phenomenon in the study of virtual reality. "...The phenomenon of Presence is that an individual experiences the illusion of being present in the same reality with objects or subjects that are not in the directly observable reality of the individual. It is necessary to make a reservation at once that in this context we are not talking about the situation of full consciousness of the individual that the reality he feels is in fact artificially created or caused to exist in another way" [1, p.38].

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The authors of [2] call the experience of presence in the virtual world mediated presence. In their opinion, the mediated presence is a sense of presence in the external world, in the realization of which technology plays an important role. When a person experiences a strong mediated presence, his/her experience shows that the technology has become a part of themselves, and the mediated reality has become a part of the Other. In the context of this work, the presence will be understood as an mediated presence.

The presence as a phenomenon can be recorded and measured. The question of selecting measurement methods is extremely important. The subjective methods, primarily questionnaires and inventoies, can be used. The behavioral and physiological measurement methods can also be used. Note that the subjective methods depend on the subjective opinion of the subjects and they do not measure presence at the moment of experience. On other hand, they are universal. The behavioral and physiological methods depend on events that trigger behavioral and physiological responses. Slater proposed a method based on breaks in presence (BiP) [3]. Most participants in virtual environments do not experience being present all the time while interacting with VR. They can hear sounds from the real world and feel the touch of objects from the real world. These sensations can cause the consciousness moves from the virtual environment to the real one. However, if a person reports a transition from the virtual environment to the real one, it means that they have just felt themselves in the virtual environment. In this way, messages about breaks in presence help to measure the presence. This method allows us to know that a participant experiences the presence at the moment when he experiences it. Slater measured the presence based on the CAVE technique and the movement around the chess table with 3D chess. The movement was carried out by walking. Slater used a mathematical model of discrete time Markov chains.

The main question of this study is whether it is possible to measure the presence by the BiP method using Markov chains in the HMD technology and moving by walking for small distances and teleporting for significant distances? Will the BiP-based presence counter measure the experience that is usually regarded to as presence? What methodological features should be taken into account? To address these question we extend Slater's approach to continuous time Marcov chain. Moreover the validity of the BiP-based presence counter was evaluated by correlation with the ITC-Sense of Presence Inventory (ITC-SOPI) [4].

Notice that in this paper, we did not set out to link the presence with any individual characteristics of the participants, we were only focused on the validity of the presence counter.

2. Background

A large number of publications have been devoted to the presence, since the 90s. From relatively old reviews, for the purposes of this paper, it is interesting [5].

Now, a number of reviews of more recent works related to the concept of presence have been published. The paper [6] provides a theoretical overview, and the paper [7] discusses methods for measuring presence, and suggests, according to the authors, unused methods. The paper [8] discusses about immersion, social presence and co-presence as the ability to be somewhere together, to perceive and be perceived by other people, to interact with people. The paper [8] also raises the question of realism and veracity.

Close to this is the discussion of perceptual and social realism as important aspects of the presence [9]. Perceptual realism occurs when the environment supports the action in it, when the response of the environment is perceived as plausible and adequate. Social realism refers to a more general concept: when an event that occurred in the environment is plausible, when it can happen in the real world. There can be high perceptual and low social realism in a virtual environment.

These concepts echo Slater's earlier ideas of place illusion and plausibility [10].

The paper [11] mentions three main approaches to the study of the presence: the mediated-objective school of thought approach, mediated-subjective school of thought approach and inner presence school of thought approach. The first two schools describe the presence as an essential element in mediated experience. The third describes the presence as a phenomenon that does not require median systems (virtual reality technologies, etc.).

The schools of the mediated presence define presence as the perceptual illusion of immediacy. [11] criticizes this approach, although pointes out that schools of mediated presence provide good definitions of a number of concepts, such as immersion and involvement. According to [11], the mediated presence approach does not answer important questions: why do we feel the presence, what is its role? Trrberti and Riva, the researchers of inner presence school raise the similar questions [12]. They also talk about the schools of mediated presence, which, according to them, do not answer questions about the evolutionary cause of the presence, about its causes and purpose.

Representatives of the third school in their works define the phenomenon of presence as a conscious sense of being in the external world, as a phenomenon that controls the division into the inner and the outer [13], [14], [15], [16], [17], [18], [19], [20], [12]. They suggest treating the presence as a presence in any environment, not necessarily created by virtual reality technology. They see the presence as a central part of conscious mental life [20]. The sense of presence, according to these researchers [12], allows you to constantly adapt your own activities to the external environment. This approach is also related to the concepts of intentions and actions: the more the environment allows you to implement intentions, turn them into actions, the stronger the experience of presence.

There are other works in which presence is considered more broadly than presence in a virtual environment. For example, [21] assumes that the presence is associated with the successful implementation of intentions, so that a person feels like a successful author of their own actions. In [**?**], the presence is considered as a personal state that occurs in both real and virtual environments, and mediation is not only a technique for creating virtual reality, but in general, any situation where actions are implemented indirectly, so presence is analyzed by the example of driving a car to demonstrate the flexibility of this approach.

Another interesting work [22] is devoted to the relationship between the presence and the perception of own movement in a virtual environment. In contrast to the researchers of the school of inner presence, who suggest that the virtual environment creates limitless possibilitiesunlimited opportunities [22] indicate that virtual environments, on the contrary, are limited in comparison with reality, in particular, it is very difficult to move. In [22] the presence and illusory self-movement in a virtual environment are linked. The experimental material shows that the presence is related to how one's own motion is perceived in a virtual environment.

We should also mention the works [23], [24], [25], devoted to the relationship of metacognitive processes and the presence. Metacognitive processes, such as monitoring and error correction, prevent cybersickness, but can also prevent the appearance of the presence, since these cognitive processes lead to the fact that a person pays attention to the low naturalness of virtual scenarios [24]. Purposeful study of different classes of psychological factors of the sense of presence will lead not only to progress in the construction of a general psychological theory of the sense of presence, but also will allow us to find effective solutions to fundamental and applied problems using virtual reality technologies [24].

The presence, regardless of the definition of which school the researcher uses, is a subjective experience in which a person interacts in one way or another with the reality surrounding him (for representatives of schools of mediated presence – virtual).

The presence measure is necessary in order to establish whether presence actually increases interaction with the virtual environment system, and to better understand the factors that may drive this phenomenon [26]. The question of a valid measure of presence was pointed in [26]. The measuring of the presence in the framework of the subjective, the behavioral and the physiological methods was consider since [27], [28].

The subjective method uses questions such as "how real did the virtual environment seem to you?", "was the virtual environment really the place you were in – or just a series of images shown to you?", [27], [28], [26], [29].

The behavioural method tracks the user's behaviour, for example, whether the user Shield himself/herself when an object is thrown at his head, [27], [28], [26], [29].

The physiological methods record changes in the heart rate, skin temperature, GSR, respiratory rate, etc. The experimenter looks at whether a person is stress in a stress situation in the virtual environment [27], [28], [26], [29].

In 2000 Slater, together with his colleagues, proposed approach to measuring presence [3]. According to Slater, traditional methods of measuring presence have certain disadvantages. In particular, the responses to the questionnaire can ensure that only conscious and voluntary responses are integrated over time. Behavioural measures, such as responding to the sudden appearance of an object, require events in the environment. The physiological measurements offer, according to Slater, a promising way forward. However, the physiological methods are used in cases where the environment causes anxiety (for example, go to a pit). That is why they are only suitable for a very small number of applications. What the physiological response is appropriate for observing a virtual chair, a room, or a deck of a ship? Relying on the physiological responses to specific events or objects in a virtual environment does not offer a general solution [30].

The main idea of the approach proposed by Slater and his co-authors can be described as follows. A person who is in the virtual reality environment switches between being present in the virtual environment and being present in the real environment [30].

Initially, Slater and Steed intended to use the mathematical model of Markov chains to calculate presence based on BiP. Later [31], the Slater team rejected this method as too complex. Natural noises was the cause of BiP in operation [3]. The noises was modeled by experimenters in later works [31].

Let as briefly describe the approach of [3] that provides main idea of method used in this paper. In the immersive virtual environment, the participant receives a continuous stream of sensory data. This data is mostly visual, coming from a virtual environment. But also often this data is auditory from the real world or real haptic and kinesthetic data (for example, the weight of the HMD). Sometimes, the sensor data of the virtual environment shows disturbances. Or a close-up of an object shows its texture mapping. Additionally data from the real world can intrude: the phone rings, there is a sudden movement of air when the door opens, the temperature changes, the cable is wrapped around the leg. Sometimes, the participants’ internal mental processes make them realize that they are actually in the virtual environment when the participant in the laboratory or exhibition hall, and not in the illusory place presented to them by the virtual environment [3].

In other words, two alternative gestalts are available to each person at any time. The first gestalt is ”I am in the place depicted by the VE system” Bellow, we following [3] denote it by “V”. The second gestalt is ”I’m in the lab in the computer science building, wearing a HMD”. This state is denoted by “R”. At every moment, the individual can occupy only one state. Being in the virtual presence in the virtual environment can be considered as the degree of preference of the state V [3].

However, during the experience of being in the virtual environment, as expected, the individual usually experiences transitions between state V and state R. These time instants when the individual switches from one interpretation to another, in particular, from V to R, are studied. It is not possible to ask participants to report transitions from R to V because this will require them to immediately exit the presence state. However, according to the authors [3] the experimenter can ask participants to report transitions from V to R. Since the transition from V to R implies the feeling of the presence, we can use this information to evaluate the being of presence.

On the other hand, the information of transition from R to V is unavailable. Thus, Slater proposed to consider two cases: low and high presence. The low presence case implies that the state “R” is basic, when the high presence case means that primary individual occupies the state “V”.

In their work, Slater and Steed provide the mathematical calculations that allow using the technique of Markov chains to derive the formula for counting the experienced presence depending on the reported BiPs. As a consequence of this formula, the probability that the participant experienced the presence is computed. The value of this probability serves as a presence counter. This formula is modified for conditions involving high presence and for conditions involving low presence [3].

Slater and Steed used the discrete time Marcov chain assuming the time unit equal to 10 seconds. Participants reported BiP orally.

In this framework, the low presence condition means that the transition from R to V occurs just before BiP. Whilst, the high presence is modeled by immidiate recovering of V after BiP.

To distinguish the low and high presence cases Slater and Steed used discriminator question.

3. Methods

3.1. Participants

The study involved 22 people, including 11 women and 11 men. With the exception of two people (men and women), all participants had or pursued the university degree.

Figure 1: General view of a virtual scene.

3.2. Equipment: hardware and software

The environment uses the vr HTC Vive headset. It connects with the computer via cables. Apart from a VR headset, the Vive system is equipped with special hand-operated controllers and with two infrared cameras for tracking a person in the environment. In order to implement both systems, the Unity 3D development environment was used, along with the C# programming language, a SteamVR plugin etc.

The most elaborated and suitable for the experiment set of visual resources was chosen at the design stage in order to create the effect of presence and immersion into the virtual environment.

Visually, the scene is a reconstruction of a classical Far-Eastern mountain monastery (see Figure 1).

3.3. Procedure

The participants were asked to provide their name, offered to wear HMD, and, having seen the virtual environment with them, follow the opened area, which is an Asian-style park. The movement was carried out by means of physical movement in a limited space and by means of successive teleportations over long distances. In the park, the participants had to fix specially selected objects along the way – low rounded vases (see Figure 2). The objects were chosen according to the principle of average notability and, at the same time, naturalness for any location of the created scene. The task was to give meaning to the walk in the park, make it purposeful and encourage the participants to move around the space of the park.

The stay in the environment was limited by 7 minutes. After the first five minutes, the participants could leave the environment at any time they wanted. The participants were instructed to say the word "here" loudly every time they felt BiP. During the experiment, an

Figure 2: Detecting a vase and indicating it with a laser pointer .

audio recording was conducted. The time at which the subjects uttered the word ”here” was recorded on an audio recording.

During the experiment, the number of vases found was also recorded. The participant could see them on the counter on his hand (see Figure 2). A large or small number of vases found were not rewarded or punished in any way.

As in the original paper by Slater and Steed the discriminator question about the experience of the presence was asked after the experiment. The participants were asked where they felt during the session. Also, the reasons for pronouncing the signal ”here” were specified. If the participant never said ”here!”, then the question ”why?” was asked. Did the participant always feel like they were here, in a real room? Did the participant feel like they were in an Asian park all the time?

The Russian version of the ITC-Sense of Presence Inventory (ITC-SOPI) was offered after the experiment. It is described in the paper [4]. This inventory is based on four factors:

- Sense of Physical Space;
- Engagement;
- Ecological Validity;
- Negative Effects.

These four factors cannot be combined into a single measure of presence. According to [4], the main determinants of the Sense of Physical Space factor are the variables of the media form, i.g., the properties of the virtual environment. The questions on this scale relate to the participants’ experiences about the reality of what is happening, the ability to touch the elements of the environment, to interact with them, ect. The second factor that is considered is Engagement. One of the points of this factor directly examines how attractive respondents find the content. Other questions that make up this scale relate to excitement and emotionality. The answers depend on the media content, but are also amplified by the media form.

The questions that include the third factor, Ecological Validity, concern the plausibility and realism of the content, as well as the naturalness of the environment. The amount, degree, and sequence of sensory stimulation, according to the authors, improves perceived naturalness and, in turn, increases scores on this scale. The high immersiveness of the media form (i.e., how it allows the participants to experience immersion), gives an increase of Ecological Validity. The higher imeressiveness is the less the impact of the content on the perception of authenticity is. The difference in photorealism also leads to differences in the scale of Ecological Validity.

The questions related to the fourth factor, negative effects, are less related to the first three factors than to each other. In [4] Negative Effects were not strongly correlated (positively or negatively) with Engagement or Ecological Validity. However, they had a low but significant positive correlation with the Sense of Physical Space. Some negative effects, such as headache, eye strain, fatigue may be associated with the media form. Further, content can affect on the Negative effects: if it is perceived as boring, the participants may give appropriate ratings of fatigue or even headache [4].

3.4. Presence counter based on BiP

The presence counter was calculated based on the probability formula of experiencing presence, which was derived using Markov chains. The formulas given in [3] were applied. Time was discrete in the work [3]. The length of the time interval was 10 seconds. Also, the presence counter at the interval length of 5 seconds was calculated to increase the sensitivity of the method. In addition, formulas for continuous time were derived.

As in paper [3] we study the stationary distribution. Notice that [32] the stationary distribution exists and moreover the Markov chain converges to it exponentially. The approach proposed in (Slater, Steed, 2000) implies that we are to solve the inverse problem: we compute the stationary distribution using the information on breaks in presence, and then we are to find the matrix of transition probabilities that provides the measure of presence. Following [3] we consider two cases. First is the low presence case. Roughly speaking, it means that the participant leaves the state of presence once he/she reaches it. The second case we examine is the high presence situation. It implies that the state no-presence is leaved once the participant reaches it.

$p_L(b)$ is the probability of presence, corresponding to the stationary distribution, for conditions of low presence at discrete time [3]:

$$p_L(b) = \frac{b-k}{n-1}$$

where
b is the number of BiPs,
n is the number of time intervals.
k is the number of ”close BiPs”, that is, BiPs in adjacent time intervals.

$p_H(b)$ is the probability of presence for high presence conditions at discrete time [3]:

$$p_H(b) = \frac{n - 1 - b}{n - 1}$$

where
b is the number of BiPs,
n is the number of time intervals.

Furthermore, we extend the approach of [3] assuming the continuous time. In this case, the dynamics of probabilities is determined by so called Kolmogorov equation that is an ordinary differential equation [32]. As above, we consider the inverse problem. We compute the matrix of transition rates by using the stationary distribution computed by BiPs. We also follow [3] and examine two cases: low presence and high-presence. However, the continuous time setting, implies that we are to introduce the relaxation time that is an external parameter. For the low presence case, it is assumed that the participant occupies the presence state once it is reached for the averaged time interval of the length μ^{-1}. The case of high presence is opposite. Here we assume that the participant will reach the presence state once he/she leaves it for the time interval of the averaged length equal to μ^{-1}. To adjust the continuous and discrete time models, one is to let μ^{-1} equal to the time unit for the original discrete time model proposed in [3].

$p_L V$ is the probability of presence for low-presence conditions at continuous time:

$$p_L V = \frac{b}{T * \mu}$$

where
b is the the number of BiPs,
T is the total time of the virtual reality session,
μ = 0.1 with a relaxation time taken equal to 10 seconds.
μ = 0.05 with a relaxation time taken equal to 5 seconds.

$p_H V$ is the probability of presence for conditions of high presence at continuous time:

$$p_H V = \frac{\mu}{\mu + \frac{b-k}{T}}$$

where
b is the the number of BiPs,
T is the total time of the virtual reality session,
μ = 0.1 with a relaxation time taken equal to 10 seconds.
μ = 0.05 with a relaxation time taken equal to 5 seconds.

3.5. Mathematical and statistical methods

In this paper, the mathematical model of Markov chains is used.

In this paper, we use the Pearson correlation coefficient for

- calculation of the relationship between the scales of the ITC-SOPI questionnaire based on the responses of the subjects to the Russian version of the ITC-SOPI;

- calculation of the relationship between the ITC-SOPI scales and different variants of calculating the probability of presence based on BiP;
- calculation of the relationship between the presence measures and the effectiveness of the search for vases, which is expressed in the number of vases found.

4. Results and discussions

The results of the ITC-SOPI questionnaire were calculated for all participants of the experiment. A BiP-based presence counter was calculated for each participant. The probability of presence is calculated when calculating the presence counter. If the participant gave a definite answer that he/she felt a presence most the time, then the formula for high presence condition was applied. If the participant gave a definite answer that he/she felt no presence or felt little presence, then the formula for low presence condition was applied. If the participant did not give a definite answer, then both formulas were applied.

Presence counter was calculated for the group of participants in the experiment 8 times according to the following principles:

The presence counter was calculated under the following frameworkes

- Time interval/relaxation time is equal 5 sec or 10 sec;
- Discrete or continuous time Markov chain is used;
- The high or low presence assumption was applied to the undecided participants

And always the high presence assumption was applied to the participants reported a high presence. Always the low presence assumption was applied to the participants reported low presence or no presence.

This gives the 8 ways of calculation of presence counter

It is nessecery to compare the presence counter with the results of the ITC-SOPI to determine the validity of the presence counter.

The ITC-SOPI results were also calculated. The Pearson's correlation analysis was performed between the scales of the questionnaire. See Table 1.

Table 1: Correlations between the ITC-SOPI scales, $r_{crit} = 0.42$ ($p \leq 0.05$) for the first level of significance, $r_{crit} = 0.54$ ($p \leq 0.01$) for the second level of significance

	Sense of Physical Space	Engagement	Ecological Validity	Negative Effects
Sense of Physical Space	–	–	–	–
Engage-ment	0.70	–	–	–
Ecological Validity	0.77	0.61	–	–
Negative Effects	-0.02	-0.04	0.13	–

Table 1 shows that the first three factors of ITC-SOPI significantly correlate with each other for the second level of significance. This corresponds to the results described in [4].

The Pearson's correlation analysis was conducted between the results of the inventory and the probabilities of experiencing presence, see Table 2.

Table 2: Correlations between the results of the questionnaire and the probability of presence based BiP, $r_{crit} = 0.42$ ($p \leq 0.05$) for the first level of significance, $r_{crit} = 0.54$ ($p \leq 0.01$) for the second level of significance

Probabilities of presence	Sense of Physical Space	Engagement	Ecological Validity	Negative Effects
The length of the time interval/relaxation time is 10 seconds				
$p_L(b)$ for uncertain and low presence; $p_H(b)$ for high presence	0.509	0.318	0.511	0.063
$p_H(b)$ for uncertain and high presence; $p_L(b)$ for low presence	0.487	0.392	0.482	0.333
p_LV for uncertain and low presence; p_HV for high presence	0.554	0.336	0.541	0.043
p_HV for uncertain and high presence; p_LV for low presence	0.551	0.416	0.520	0.241
The length of the time interval/relaxation time is 5 seconds				
$p_L(b)$ for uncertain and low presence; $p_H(b)$ for high presence	0.577	0.350	0.541	-0.015
$p_H(b)$ for uncertain and high presence; $p_L(b)$ for low presence	0.349	0.348	0.403	0.355

$p_L V$ for uncertain and low presence; $p_H V$ for high presence	0.657	0.378	0.592	-0.051
$p_H V$ for uncertain and high presence; $p_L V$ for low presence	0.538	0.428	0.523	0.355

Table 2 shows that the probabilities of presence significantly and positively correlates with the two scales of the questionnaire. These scales are Spatial Presence and Ecological Validity. The highest correlation values, significant for the second level of significance, were obtained when comparing the first and third ITC-SOPI scales with the probabilities of presence, calculated using a formula designed for low presence condition for the participants who did not give a clear answer or gave an answer about low presence, and using a high presence formula for the participants who gave a certain answer about high presence, for continuous time with a relaxation time taken equal to 5 seconds. This shows that this formula allows to create the most sensitive presence counter. However, when calculating the probabilities of presence using a formula designed for high presence conditions for the participants who did not give a clear answer and for the participants who reported high presence, and using a low presence formula for the participants who reported low presence or did not experience it, for continuous time with a relaxation time taken equal to 5 seconds, a correlation of the probability of presence with the Engagement scale was obtained.

Since, see Table 1, the first three ITC-SOPI scales correlate with each other, this result seems to be natural.

The relationship between the presence counter, which represents the probability of presence, and the ”Sense of Physical Space” scale seems obvious. The presence counter is based on BiP and the participants were instructed to report BiP every time they felt like they were in a real room, not in an Asian park. Therefore, it is obvious that the presence counter should correlate with the scale associated with the participants' experiences about the reality of what is happening, the ability to touch the elements of the environment, to interact with them.

The focus on the environment, as measured by the second scale, ”Engagement”, can also affect whether a participant feels like they are in a virtual environment or in a real room. However, this issue needs further clarification.

Apparently, the naturalness and plausibility of the environment, as measured by the ”Ecological Validity” scale, also influenced how the participant felt in the virtual environment.

It should be understood that the application of the formula of high presence conditions for undecided participants does not in itself give more valid results. The greater validity of the results, in which the probability of presence in undecided participants is calculated using the low-presence condition formula, is due to the fact that this formula seems to reflect the presence they experienced more than the high-presence condition formula. The correlation between the two indicators suggests that one will change in the same way as the second. In our case, the probability of presence calculated using BiP is expected to increase or decrease in the same way as the ITC-SOPI scales. The method of calculating the probability of presence has this property to the greatest extent, when the formula of high presence conditions is used for those participants who indicated a high presence, and the formula of low presence conditions is used for those who indicated a low presence or no presence and for those who were undecided. But of course we get the significative correlation between ITC-SOPI scale "Engagement" and the presence counter using the formula of high presence conditions for those participants who indicated a high presence and for those who were undecided, and the formula of low presence conditions for those who indicated a low presence or no presence.

To clarify the optimal formula, additional studies will be required on an extended sample group and with a more strict discriminant question.

The number of vases found by the participants was also calculated, but it was not related to either the results of the presence counter or the results of the ITC-SOPI, see Table 3.

Table 3: Results of calculating the correlation between the number of vases found and marked by the subject during the experiment and the presence indicators, $r_{crit} = 0.42$ ($p \leq 0.05$) for the first level of significance, $r_{crit} = 0.54$ ($p \leq 0.01$) for the second level of significance

Presence indicators	Correlation between the number of found vases and the presence indicator
The length of the time interval/relaxation time is 10 seconds	
$p_L(b)$ for uncertain and low presence; $p_H(b)$ for high presence	0.143
$p_H(b)$ for uncertain and high presence; $p_L(b)$ for low presence	-0.271
$p_L V$ for uncertain and low presence; $p_H V$ for high presence	0.163
$p_H V$ for uncertain and high presence; $p_L V$ for low presence	-0.248
The length of the time interval/relaxation time is 5 seconds	
$p_L(b)$ for uncertain and low presence; $p_H(b)$ for high presence	0.124
$p_H(b)$ for uncertain and high presence; $p_L(b)$ for low presence	-0.285
$p_L V$ for uncertain and low presence; $p_H V$ for high presence	0.168
$p_H V$ for uncertain and high presence; $p_L V$ for low presence	-0.245
Results of ITC-SOPI	
Sense of Physical Space	0.242
Engagement	0.002
Ecological Validity	0.164

Negative Effects	-0.214

The effectiveness of vases search is not related to the presence, as shown in table 3. It can be assumed that the presence does not affect the performance task related with the objects search and the objects search does not affect the presence.

5. Conclusion

In this study, we considered the measuring presence of the using primarily information available during the session of interacting with the virtual reality that does not require an emotionally rich content of the environment. Such a measure is a presence counter based on the calculation of the probability of presence using the Markov chain model. During the session, the participant reports the BiP, while continuing to perform the task. In this experiment, we used an environment that was an Asian park, where the participants could move around using teleportation and find vases. The experiment showed that the number of vases found during the session is not related to the presence measured during the experiment.

The paper shows that the presence counter based on BiP is a valid measure of presence for HMD technology and environment containing moving by walking for small distances and teleportation for significant ones. The presence counter provides the same measure of presence as the ITC-SOPI, which showed the high level of internal consistency in the Russian-language sample group. The formula based on continuous time seems to be more productive, especially since time is actually a continuous quantity, not a discrete one. The obtained results can be improved when we perform the study with largest group and clarify the discriminator question.

Thus, the results show that calculating the probabilities of presence using a formula designed for high presence conditions for continuous time Markov chain with the relaxation time taken equal to 5 seconds is optimal and allows to create the most sensitive presence counter. However, the experimental procedure allows for uncertainty in the subjects' responses to the discriminator question whether they felt a presence. Therefore, it was necessary to use both the formula for high-presence conditions and the formula for low-presence conditions for undecided participants. It will be profitable to find a more strict discriminator question that does not give uncertainty. Moreover future works include the improvement of instructions. The fact that the presence counter calculated on the basis of BiP has a significant correlation with the three of ITC-SOPI scales, that is, not only with "Sense of Physical Space", but also with "Ecological Validity" and with "Engagement", looks very interesting. Obviously, the presence counter measures how much the participant feels in the virtual environment and also how much they perceive the environment as plausible and natural. The presence counter also measures how much the participant is involved in the events of the environment.

Future research should also include virtual experiences related to different environments, participants' capabilities, and tasks. When the procedure for applying the presence counter is clarified, it will be possible to raise the question of the relationship between the presence deducted using the BiP-based presence counter and various individual characteristics of participants, such as gender of respondents, age, degree of familiarity with virtual reality, attitudes associated with participation in the experiment and so on.

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