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# Influence of shifting attention and absorption on spatial presence formation

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**Abstract**

*This paper presents results of an experiment investigating the influence of attention shifting efficacy and absorption on the process of spatial presence formation in the context of forced breaks in presence procedure. Using roller coaster scenario as virtual environment, it was found that shifting ac- curacy affects self-referential and objectively measured sense of presence, especially in interaction with predisposition to external absorption. In conclusion, it is suggested that received results might reflect costs of shifting between environments, on the one hand, and the influence of distractors perception threshold level, on the other. Further research employing neuroimaging methods and an odd-ball task as forced BIP procedure is proposed.*

*Keywords*---**spatial presence, shifting attention, absorption, breaks in presence**

## 1. Introduction

Significance of cognitive processes in forming feeling of spatial presence in virtual environment was acknowledged in most of the existing models [1,2,3]. Nevertheless, the importance of cognitive control seems to be largely ignored [4]. Admittedly, it is included in some models [2], but still more detailed research is needed. In this paper the problem of influence of shifting attention [4,5] and absorption [6,7] on spatial presence formation is being explored.

'Presence' is a theoretical construct describing humans' re- action on virtual reality exposition. Most frequently it is defined as 'a sense of being there' (into virtual environment) [8,9]. The present study focuses on spatial presence – one of a few identified types of presence [9,10]. According to definition proposed by ISPR [9] and used by Wirth and colleagues [2], spatial presence is 'a sense of being there, occurring when part or all of a person's perception fails to accurately acknowledge the role of technology that makes it appear that one is in a physical location and environment different from one's actual location and environment in the physical world' [9].

In order to explain the formation of spatial presence sever- al theoretical models were constructed [1,2,3]. Nonetheless, only three are relevant to understand the hypothesis postulated in the present study. At first, two pole model [1], which claims that during VE exposition people tend to switch between two available environments – virtual and physical. This process might be also perceived as shifting between 'being' and 'not being present' in VE. Thus, this model implies rather binary character of presence.

The three pole model is an amplification of the previous one. Biocca [3] proposes adding a third pole – mental imagery space. According to him, two additional processes influence feeling of presence formation, i.e. spatial attention and spatial updating. The former decides about being present in mental imagery space or in external world, the latter determines being present in virtual or physical space.

Finally, The Measures, Effects, Conditions (MEC) model [2] postulate that spatial presence formation is a two-step process. At the beginning, the spatial situation model (SSM) of virtual environment is constructed, which might be accepted or rejected during the "medium-as-PERF-hypothesis" (PERF = primary egocentric reference frame) testing. When hypothesis is approved, spatial presence appears. Authors enumerate many factors influencing the described above process, with absorption, attention allocation and suspension of disbelief among them.

To sum up, the three introduced models have been chosen because of some assumptions about attention allocation processes importance in spatial presence formation.

### 1.1. Shifting attention and presence

Shifting between tasks or mental sets is indicated as one of the main cognitive control functions [4]. It is understood either as a process involving back and forth between multiple tasks, mental sets, operations, or as a process involving the disengagement of an irrelevant task

set and the subsequent active engagement of a relevant task set.

Although shifting is often associated with attention switching, it is not tantamount with the process of switching visual attention by making appropriate voluntary eye movements. Shifting is rather perceived as a controlled process, involving frontal parts of the brain [4], especially dorsolateral prefrontal cortex [5].

Analyzing the models of spatial presence formation, some conclusions about the significance of shifting capability in this process can be drawn. In the two pole models [1], efficacious switching between competing environments might influence a global sense of presence reported after the end of virtual reaity session. In the MEC model [2], effective switching may help on both levels of spatial presence formation, namely by enabling focus on virtual environment, despite distractors coming from the physical 'world'. Finally, shifting seems to be important in processes of spatial attention described by Biocca [3].

Moreover, results from neuroimaging methods deliver some confirmation to this assumption [11]. The data imply crucial role of dorsolateral prefrontal cortex (DLPFC) as a modulator of the feeling of spatial presence. Strictly speaking, the higher DLPFC activation, the weaker feeling of spatial presence. It is suggested that DLPFC might be involved in control of the egocentric processing [2] of the virtual environment stimuli. What is important, this hypothesis seems to be in line with MEC model assumptions about testing the medium-as- PERF-hypothesis.

Thus, it is likely that DLPFC activation, discovered by Baumgartner and colleagues [11], reflects an intensity of switching between two competitive egocentric reference frames – virtual and physical. In this context, shifting efficacy seems to be crucial in the spatial presence formation.

## 1.2. Model of spatial presence formation in the context of forced breaks in presence procedure.

In order to investigate dynamics of spatial presence formation, especially the role of shifting efficacy, special procedure aimed for objective presence measurement is proposed in this study. The task is constructed on basis of Snodgrass' and Lynn's [12] classic experiment on absorption and Slater's and Steed's breaks in presence (BIP) method [13].

Strictly speaking, in the forced breaks in presence procedure, during exposition on a virtual environment, participants have to react as fast as possible on certain

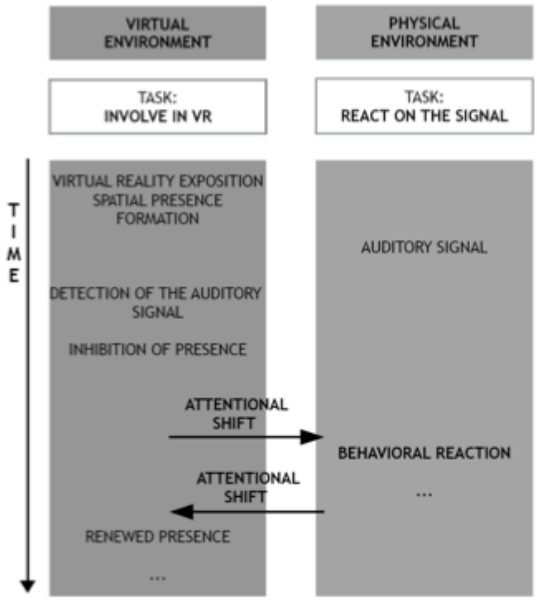


**Figure 1: Model of spatial presence formation in the con- text of forced breaks in presence procedure**

auditory signals. In this situation, the dynamic of presence formation is thought to be as it is presented on Figure 1. As it is depicted in Figure 1, several cognitive processes are thought to be involved in spatial presence formation in the context of forced breaks in the presence procedure. Detection of auditory signals, inhibition of sense of presence and shifting attention between two environments are perceived as the most important ones.

## 1.3. Hypothesis

Taking into consideration cognitive processes, postulated by the above-presented model, some hypothesis concerning a dynamics of spatial presence formation can be formulated.

At first, it is suggested that shifting efficacy influences feeling of presence. Thus, the first hypothesis is as follows: the more efficient the shifting, represented by lower costs of shifting, the stronger the feeling of presence, measured subjectively and objectively. This hypothesis is based on assumption, that high competence in shifting do not impairs the feeling of presence, when a switch between two environments is required (like in forced BIP procedure).

Before formulation of the next hypothesis it is necessary to introduce another important variable, considered as crucial in the proposed model: the absorption [6]. In the following study, Polczyk's [7]

conceptualization of this terms is used. He focused on attentional aspect of absorption, called predisposition to absorption and defined it ‘as an ability to intensive focus of attention, characterized by high stimuli perception threshold for stimuli unconnected with the subject of attention’. Thus, attentional component of absorption, may play a role in detection of the auditory signal in forced BIP procedure. Additionally, previous studies also suggested influence of absorption on feeling of presence [14]. Therefore, the second hypothesis of this study postulates that predisposition to absorption is positively correlated with feeling of presence, measured in the context of forced BIP procedure.

To sum up, the main aim of this study is to investigate the importance of shifting attention efficacy and absorption in the process of spatial presence formation during forced breaks in presence procedure. Both terms seems to reflect two aspects of attentional processing: detection (predisposition to absorption) and switching (shifting). Thus, they are likely to influence two processes identified in forced BIP procedure: detection of the auditory signal and attentional shift.

## 2. Method

Participants: Fifty seven healthy male and female volunteers (M = 24,02 years; SD = 1,83 years) participated in the experiment. They were undergraduate and graduate students from three Krakow's universities (Jagiellonian University, AGH University of Science and Technology, Cracow University of Technology). All of them signed an informed consent.

Apparatus: In order to measure all important variables a few measures was used.

Shifting attention efficacy was assessed by two computer tasks. Both of them measured speed and accuracy of shifting between two, randomly activated criteria of stimuli categorization. On the basis of individual results, two indicators of shifting attention efficacy was calculated – general speed and general accuracy, both reflect costs of shifting for each participant in reference to mean results of the whole group. General speed of shifting was constructed as follows:

step 1: calculating mean cost of shifting in task 1 (MRT1 = RT in shift trials – RT in no-shift trials),

step 2: calculating mean cost of shifting in task 2 (MRT2 = RT in shift trials – RT in no-shift trials),

step 3: calculating mean cost of shifting in both tasks – general speed of shifting [MRT = (MRT1 + MRT2)/2],

step 4: standardized to Z-scores – calculating Z-value of MRT for each participant.

Thus, received indicator is interpreted as follows: the higher a Z-value of MRT, the higher cost of shifting, i.e. worse shifting. The second indicator – general accuracy of shifting (MERR) was created analogically.

Absorption level was assessed using the Predisposition to Absorption Scale [7] – Polish conceptualization of this term. The scale consists of 49 statements, requiring 'yes' (1) or 'no' (0) answers. The higher the score, the greater the absorption. Moreover, the factor analysis identified three subscales: internal absorption, external absorption and absence. In present study, the second one is the most important. Reliability of the scale is satisfactory with Cronbach's alpha equals 0,88 and halves reliability equals 0,79. Validity of the Polczyk's scale was evaluated in reference to TAS (Tellegen Absorption Scale; Tellegen i Atkinson, 1974) and showed that covariance is not higher than 30%. Polczyk's suggested that his idea of predisposition to absorption, defined as attentional predisposition, is only

**Figure 2: Roller coaster ride.**

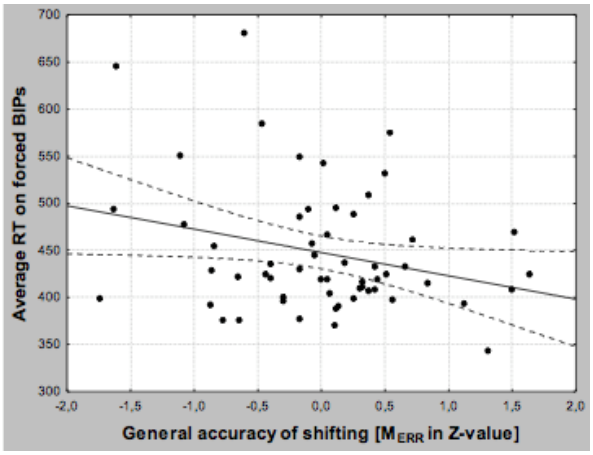


**Figure 3: Correlation between self-referential feeling of presence and general accuracy of shifting.**

the part of the concept proposed by Atkinson and Tellegen.

The free roller coaster scenario was used (www.nolimitscoaster.com) as a virtual reality environment. Two rides were run with total time of about 4 minutes (276 seconds). Because of lack of access to highly immersive technologies, simulation was presented with use of projector and screen (235 x 175 cm). In order to produce an illusion of sitting in a bogie, participants were situated on high (60 cm) box with the screen located on eye level (see: Picture 1).

Behavioural measure of presence – forced breaks in presence procedure, was constructed. During VRE presentation auditory signal was emitted and participants had to react as soon as they heard it. The indicator of presence was the average reaction time (RT), interpreted as follows: the higher RT, the greater the feeling of

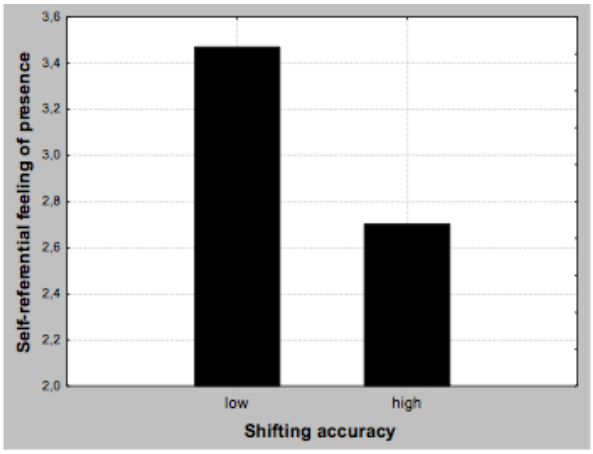


**Figure 4: Average self-referential feeling of presence dependency on shifting accuracy**

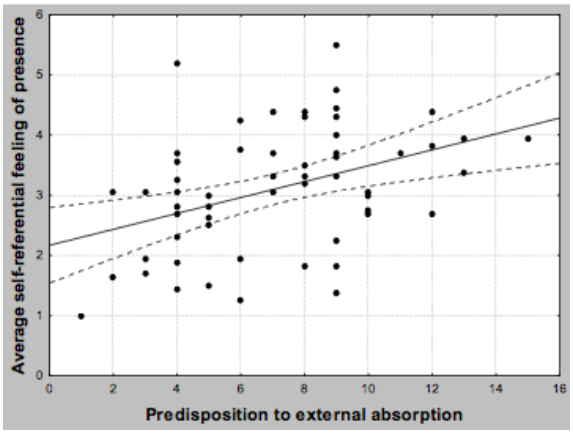


**Figure 5: Correlation between self-referential feeling of presence and predisposition to external absorption**

presence. During the roller coaster ride auditory signal was presented 25 times with variable interstimulus interval, for each participant in the same order. The sound was not the part of roller coaster scenario, it was emitted by independent speaker, located in front of participants.

At the end, level of subjective feeling of presence was assessed by the Polish version of presence questionnaire [15]. The scale consists 16 questions, with Lickert scale format of answer (from 0 – not at all to 6 – completely). Polish adaptation was based on analysis of a few English versions of presence questionnaires. Final form of Polish scale was constructed on basis of pilot study [15]. The initial version consists of 50 items after statistical analysis was reduced to final 16 items. Reliability of the scale is satisfactory with Cronbach's alpha equals 0,93 and inter-item reliability 0,5.

Procedure: The experiment was conducted in a classroom, in Jagiellonian University Institute of Psychology. At the be- ginning all participants signed an informed consent. Then shifting attention efficacy was measured with two computer task, each lasting about 7 minutes, starting with instruction presentation and a short training. Subsequently, participants filled in the Predisposition to Absorption Scale. After that, all of them were acquainted with forced break in presence procedure. Finally, they were instructed to involve in virtual environment scenario and, at the same time, react on auditory signal by pushing the appointed button as quickly as they could. At the end, level of subjective feeling of presence was assessed by the Polish version of presence questionnaire. The whole experiment lasted about half an hour for each participant.

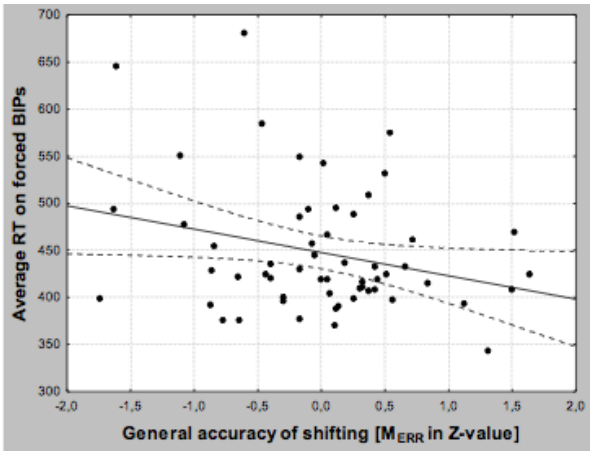


**Figure 6: Correlation between behavioural measure of presence and predisposition to absorption.**

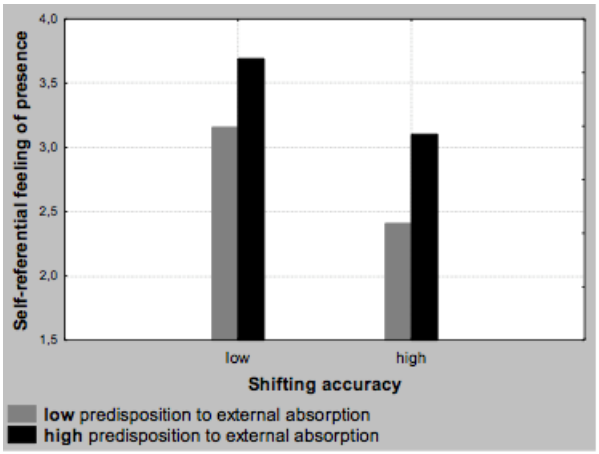


**Figure 7: Influence of dichotomized predisposition to external absorption and dichotomized self-reported feeling of presence interaction on self-referential presence.**

## 3. Results

Data analysis was performed using STATISTICA. The obtained significant results are as follows:

Surprisingly, there was no significant correlation between two measures of presence – self-referential and behavioural (r = - 0,12; ns).

Collected data did not support the first hypothesis. In fact, results were contrary to the expectation. Strictly speaking, general speed of shifting (MRT) did not correlate with score in used presence measures (self-referential and behavioural). However, there was significant negative correlation between general accuracy of shifting (MERR) and self-referential presence (r = - 0,27; p < 0,05; see: Figure 3). Thus, the higher was the general accuracy of shifting (i.e. higher costs of shifting), the larger was mean reaction time in forced BIPs procedure.

Paradoxically, after dichotomization regarding participants' global accuracy of shifting (highly vs lowly accurate), it appeared that highly accurate persons (M = 2,70; SD = 0,93) reported lower subjective presence than lowly accurate (M = 3,45; SD = 1,00) (Student's t-test: t = 2,90; p < 0,01; see: Figure 4).

On the other hand, results supported the second hypothesis. Positive correlation between level of predisposition to absorption and self-referentially assessed presence was found (r = 0,36; p < 0,01). Furthermore, slightly stronger correlation was found in case of one of the subscales – predisposition to external absorption (r = 0,40; p < 0,01; see: Figure 5).

Moreover, predisposition to external absorption correlated negatively with behavioural measure of presence – mean RT in forced BIP (r = - 0,31; p = 0,02; see: Figure 6).

Significant results were provided by MANOVA analysis. Interaction between dichotomized predisposition to external absorption and dichotomized global accuracy of shifting, explains some differences in level of both self-referential and objectively measured sense of presence. The most interesting result indicates that persons with combination of low predisposition to external absorption and high shifting accuracy (M = 2,41; SD = 0,81) reported significantly lower level of self-referential presence (t = - 4,27; p < 0,01; see: Figure 7) than participants with opposite combination of these features (M=3,69, SD

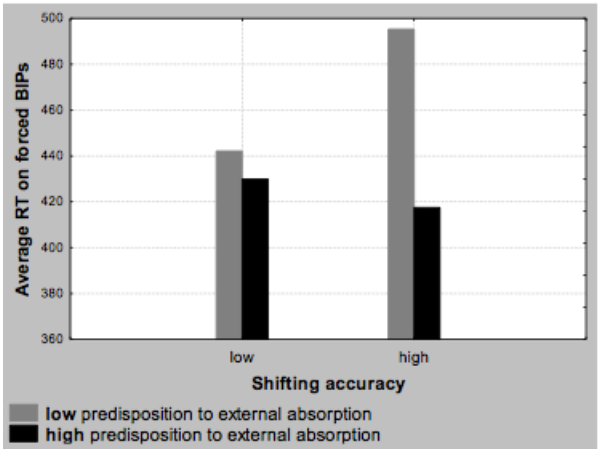


**Figure 8: Influence of dichotomized predisposition to external absorption and dichotomized self-reported feeling of presence interaction on behavioural measure of presence.**

=0.88).

Paradoxically, comparing level of objectively measured presence (RT on forced BIPs) achieved by the same two groups showed opposite effect – persons with combination of low predisposition to external absorption and high shifting accuracy (M = 495,33; SD = 88,46) demonstrated significantly slower RT on forced BIP (i.e. higher presence; t = -2,51; p < 0,05; see: Figure 8) than participants with opposite combination of these features (M = 429,95; SD = 57,71).

## 4. Discussion

Collected results seem to partly support the postulated hypothesis. Despite some of the data is not in line with the initial intuitions, it instigates to draw these conclusions.

At first, no correlation between two used measures of presence indicates that they might reflect different aspects of feeling of presence. Detected disparity have already been noticed in presence studies [16]. Some authors even postulate that self- referential tools may not measure presence properly [17]. Furthermore, it is likely that mean reaction time on auditory signal in forced BIP procedure, reflects rather intensity of feeling of presence in physical world, than in virtual environment. Thus, it is suggested to interpret RT on forced BIPs as indicator of feeling of presence in physical environment as follows: the higher RT, the less presence in physical world. On the other hand, self-referential measure might reflect feeling of presence in virtual environment. Such distinction seems to be in line with Biocca's three-pole model, which postulates that feeling of presence might be either divided or undivided [3]. In this con- text, high score in self-referential measure of presence might reflect undivided (high) presence in virtual environment, while low mean reaction time in forced BIP procedure may indicate undivided (high) presence in physical environment. Nevertheless, low feeling of presence in VE do not always equals high presence in physical environment and vice versa. Further re- search is needed in order to construct measures clearly differentiating between presence in virtual environment, physical environment or mental imagery space.

What is important, first hypothesis, which postulates relationship between shifting attention efficacy and feeling of presence, was only partially confirmed. Firstly, general speed of shifting does not correlate with feeling of presence in VE. However, results indicate that the higher the cost of shifting (general accuracy of shifting; see: Method – Apparatus), the longer mean reaction time on forced BIPs. In other words, the worse is shifting accuracy, the weaker is feeling of presence in VE, assessed by behavioural measure. On the other hand, after dividing the group on highly vs lowly accurate participants, it was found out that highly accurate participants reported weaker feeling of presence (expressed in subjective measure) than lowly accurate subgroup.

Taking into consideration these divergent results, it is suggested that accurately shifting persons, lose in both environments: they feel weaker subjective presence and react slower on forced BIPs. Thus, shifting accuracy seems to be somehow important to formation of spatial presence. It is likely that high accuracy of shifting is connected with divided form of presence [3]. On the other hand, forced BIP procedure might require of- ten switching between PERFs [2], thus participants highly ac-curate in shifting, may have problem with unambiguous chose of PERF, which results in lower presence in available environments. In order to disentangle role of PERF changes in feeling of spatial presence formation, further research with use of neuroimaging methods may be conducted to provide additional information about DLPFC (structure important in egocentric spatial processing [18]) activation during shifting between two environments in forced BIPs procedure.

Going further, the collected data only partly supported the second hypothesis, postulating positive correlation between predisposition to absorption and feeling of presence in virtual environment, measured both objectively and subjectively. On one side, predisposition to absorption, especially predisposition to external absorption, correlates positively with self-referential measure of presence. On the other hand, negative correlation between predisposition to absorption and behavioral measure of presence was found. Thus, dissociation between both used measures has been confirmed once again. Correlation between two self-referential measures – Polczyk's Predisposition to Absorption Scale [7] and Polish version of presence questionnaire [15] is not surprising in face of earlier studies on absorption and presence [for a review: 14]. Additionally, it may result from self-referential character of both measures.

However, negative correlation between predisposition to absorption and behavioural measure of presence, indicates that the higher the predisposition, the faster reaction time on auditory stimuli (forced BIP). Taking into consideration above interpretation of differences between self-referential and behaviour- al measures of presence, it might be suggested that higher pre-disposition to absorption correlates positively with

undivided presence both in virtual and physical reality [3]. Furthermore, Polczyk's [7] explanation of predisposition to external absorption, defined as ability to intensive focus of attention on extern- al stimuli (e.g. film, music, piece of art), which results in higher threshold of perception of stimuli unconnected with the subject of attention, provide another explanation for the received data pattern. Strictly speaking, more intensive focus of attention may be connected with undivided form of presence.

Additionally, interaction between dichotomized predisposition to external absorption and dichotomized shifting ac- curacy seems to explain some differences in feeling of presence intensity. Discovered pattern of results indicates that combination of low predisposition to external absorption and high shifting accuracy results in lower self-referentially measured presence and higher behaviourally measured presence, than in case of reverse combination of these two features. Alternative interpretation, consistent with Biocca's model [3], indicates that combination of low predisposition to external absorption and high shifting accuracy might correlate with divided presence, i.e. low presence in VE (low score in Polczyk's Predisposition to Absorption Scale) and low presence in physical environment (long RT on forced BIP). On the other hand, the opposite con- figuration: high predisposition to external absorption and low shifting accuracy may result in undivided presence, i.e. high presence in VE (high score in Polczyk's Predisposition to Absorption Scale) and high presence in physical environment (fast RT on forced BIP).

## Conclusions

Taking into consideration the obtained results and postulated model of spatial presence formation in case of forced BIPs procedure, it is concluded that efficacy of shifting (especially accuracy) might influence this process by affecting shifting attention between two environments. Additionally, absorption level seems to have an impact on a detection process by affecting perception threshold level. Nonetheless, in order to un- ravel this problem, further research is needed, especially with neuroimaging methods employment. Also, using odd-ball task [19] instead of simple reaction time in forced BIPs procedure might shed light on attentional processes playing role in forced breaks in presence procedure. During odd-ball task at least three types of auditory signals are presented with different frequency (standard vs deviant). Dependently on version, participant has to either only listen to this signals (passive odd-ball) or react on a signal marked as a target (active odd-ball). EEG activity is registered during task performance. Further analysis of event-related potentials (ERP) enables to investigate different stages of information processing. Comparing electro - physiological data collected in odd-ball task with individual differences in feeling of presence, predisposition to absorption and shifting accuracy might help to disentangle the complex relationship between attentional processes and feeling of spatial presence formation.

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