EEG Analysis on 3D Navigation in Virtual Realty with Different Perspectives

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ABSTRACT
In this paper we explore the relations between perspectives of navigation and electroencephalogram (EEG) in 3D virtual space. We analyze three types of navigation with EEG recordings and examine how the perspectives affect the users' electrical activities in their brains. Via a small-scale experiment, we find that the influence of peripersonal space is altered by the perspective, and it can be observed via EEG monitoring. These results have interesting implications on virtual reality applications where a sense of agency, or a peripersonal task takes important roles.

Author Keywords
Navigation; Virtual Space; Perspective; Human Agent Interaction; Electroencephalogram (EEG)

ACM Classification Keywords
H.1.2. User/Machine Systems: Human Factors; H.5.1 Multimedia Information Systems: Artificial, augmented, and virtual realities

INTRODCUTION
In recent decades, many researches on neurocognitive science have been conducted, and they had tremendous impacts on our knowledge of how human perceives the world and reacts accordingly. One of the fascinating studies is about spatial cognition, which should be a useful guide for designing navigation experience in 3D virtual space. There are three regions in human spatial cognition: personal space, peripersonal space, and extrapersonal space [7]. These three regions are independent of each other but they work together as one intricate visual perception system.

When designing a 3D virtual space, these cognitive regions of a user might take important roles on the quality of a task accomplished. Saucier et al. [8] suggest in their study that female excels at tasks performed in peripersonal space. Moreover, increase in peripersonal space may affect the sense of agency [5]. Peripersonal space can be extended by a tool use [1] as well as emotional or social context [2].

The aforementioned studies confirm that peripersonal space has its own significant influence on human cognition in physical world. In this study, we attempt to explore the possibilities of manipulating peripersonal space with various perspectives in 3D navigation, which can be observed in terms of brain activities.

STUDY DESIGN
The subjects were asked to watch three video clips of art gallery navigation within 3D environments with different perspectives, after electroencephalogram (EEG) setup procedures. The video clips were created from Unity games that are available on the Unity Asset Store[1], and the video clips were recorded with a simple scenario: Each sequence ends as the avatar or the viewpoint of the camera arrives at the opposite of the wall. As shown in Figure 1, three sequences were shown to the subjects: (a) a first-person perspective (1PP) sequence without avatar in an art gallery, (b) a 1PP sequence with a tool (gun) as the extended part of subjects' virtual arms, and (c) a third-person perspective (3PP) sequence with a human avatar. The video clips have a frame rate of 24 Hz and lengths of 25 seconds.

Participants
Three volunteer subjects with normal visual acuity (one male and two females; age=22-24 years) participated in the experiment, which took about half an hour for each subject. All participants were right-handed and new to the game we used in this experiment. Subject #1 was an experienced gamer both with 1PP and 3PP games, subject #2 had some

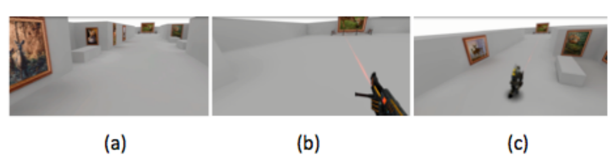

Figure 1. Three video clips: an art gallery environment with (a) no avatar, (b) 1PP avatar, (c) 3PP avatar

[1] https://www.assetstore.unity3d.com/

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gaming experience, and subject #3 had little gaming experience.

Experiment Procedure

The video clips were displayed on a computer monitor (21x12 inches, 1980x1080 pixels), which was placed 22-27 inches apart from each participant. Subjects were asked to watch the three video clips continuously with two 10-second breaks in-between consecutive sequences. A plane black screen was shown during the breaks to be used as baseline recordings.

EEG was recorded from a 32-channel ActiveTwo system of Biosemi, using the standard cap layout based on the International 10-20 system. The digital sampling rate was 1024 Hz, and the data were bandpass-filtered from 2 to 100 Hz after recording EEG. Then, we used an independent component analysis (ICA) algorithm of EEGlab software to correct artifacts. The resulting signals are analyzed in the frequency domain in a way that the power in each frequency band (alpha, beta, gamma, and theta) is computed, which was normalized by subtracting the power for the baseline period.

RESULTS

Figure 2 shows the average power across the subjects for each frequency band, and Figure 3 shows relative powers between the three perspective cases for each subject.

As shown in Figure 2, all cases show high activities in the beta and gamma brainwaves in the frontal regions. Among three perspectives, (b) *1PP with avatar* has the highest means of beta and gamma powers, and (a) *1PP without avatar* and (c) *3PP with avatar* have the next highest values of beta and gamma in order. It is well known that beta wave is displayed during active thinking and focus, and gamma is shown during cross-modal sensory processing [4].

According to the study in [6], peripersonal space is subserved by a set of interconnected parietal and frontal regions of the brain. It is also suggested in [3] that peripersonal space is coded in the specific area called inferior premotor cortex (F4 electrode) located in frontal region. In Figure 2, the right side of the frontal regions exhibits high EEG powers in most of the perspectives, though with different average values.

In our experiment, the subjects were asked to compare the level of agency of each perspective after the experiment, and the results were: subject #1: (b)-(a)-(c), subject #2: (b)-(c)-(a), subject #3: (b)-(c)-(a). If only looking at the F4 region in Figure 3, it seems that the results represent well the reported sense of agency of each individual, especially, subject #1 who preferred *1PP without avatar* over *3PP with avatar*.

It can be deduced from the result that *1PP with avatar* has more sense of agency and extends peripersonal space. This result may insinuate that peripersonal space can be manipulated by perspectives in 3D virtual environments.

CONCLUSION

In this work we analyzed the EEG data from 3D navigation in virtual reality and suggested that there might be a possible correlation between perspectives and alteration of peripersonal space, which can be observed in the brain activity.

Ultimately, we hypothesize that manipulating perspectives can alter peripersonal space and consequently provide new user experience in 3D virtual space. We are working in progress in this direction. In particular, we will study how extended peripersonal spaces with various tool usages with emotional/social contexts affect the quality of cognitive tasks in 3D virtual environments.

ACKNOWLEDGMENTS

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REFERENCES

1. Berti, A. and Frassinetti, F. When far becomes near: remapping of space by tool use. *Journal of Cognitive Neuroscience 12*, (2000), 415–420.
2. Clery, H., Guipponi, O., Wardak, C., and Hamed, S. B. Neuronal bases of peripersonal and extrapersonal spaces, their plasticity and their dynamics: Known and unknowns. *Neuropsychologia 70* (2015), 313-326.
3. Fogassi, L., Gallese, V., Fadiga, L., Luppino, G., Matelli, M., and Rizzolatti, G. Coding of peripersonal space in inferior premotor cortex (area F4). *Journal of Neurophysiology 76* (1996).
4. Kisley, M. A. and Cornwell, Z. M. Gamma and beta neural activity evoked during a sensory gating paradigm: Effects of auditory, somatosensory and cross-modal stimulation. *Clinical Neurophysiology 117*, 11 (2006), 2549–2563.
5. Maravita, A., Spence, C., and Driver, J., Multisensory integration and the body schema: close to hand and within reach. *Current Biology 13*, (2003) R531–R539.
6. Pellegrino, G. d. and Ladavas, E. Peripersonal space in the brain. *Neuropsychologia 66*, (2015) 126-133.
7. Robertson, I. H. and Halligan, P. W. Spatial Neglect: A Clinical Handbook for Diagnosis and Treatment. Psychology Press (1999).
8. Saucier, D., Lisoway, A., Green, S., and Elias, L. Female advantage for object location memory in peripersonal but not extrapersonal space. *Journal of the International Neuropsychological Society 13*, (2007), 683-686.

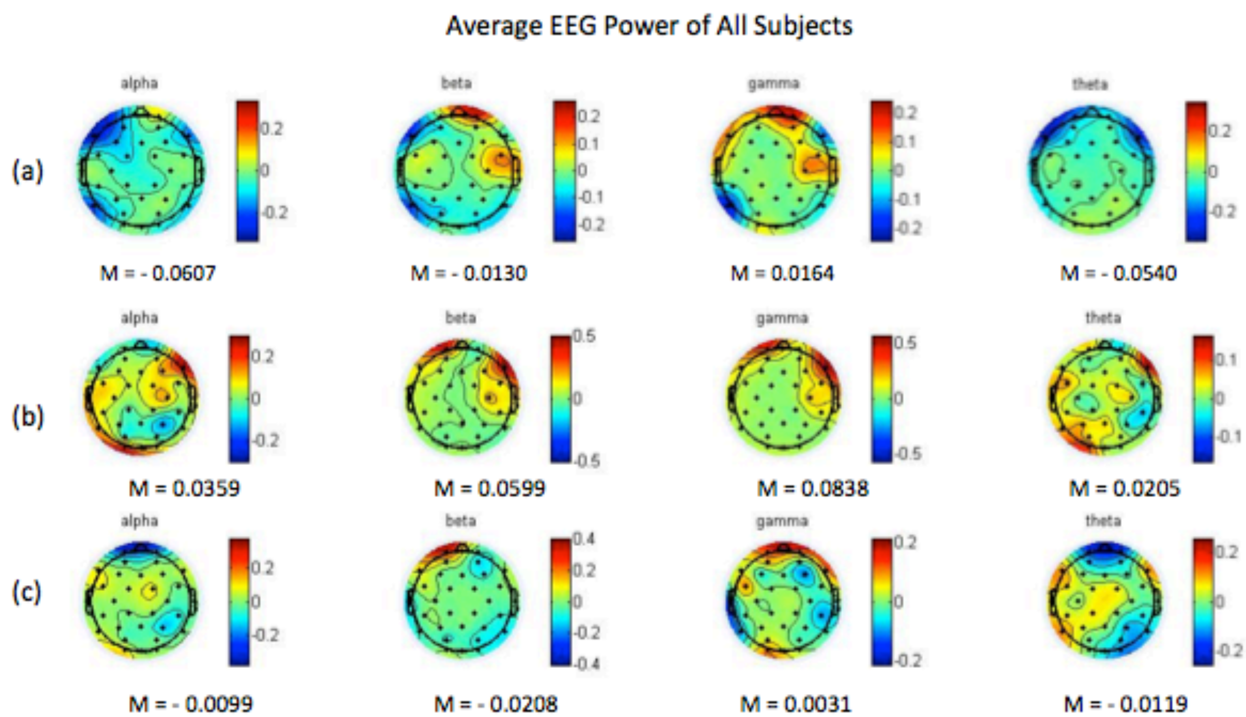

Figure 2. Average EEG power of all subjects with means of each brainwaves: (a) *1PP without avatar*: alpha=-0.0607, beta=-0.0130, gamma=0.0164, theta=-0.0540, (b) *1PP with avatar*: alpha=0.0359, beta=0.0599, gamma=0.0838, theta=0.0205, (c) *3PP with avatar*: alpha=-0.0099, beta=-0.0208, gamma=0.0031, theta=-0.0119.

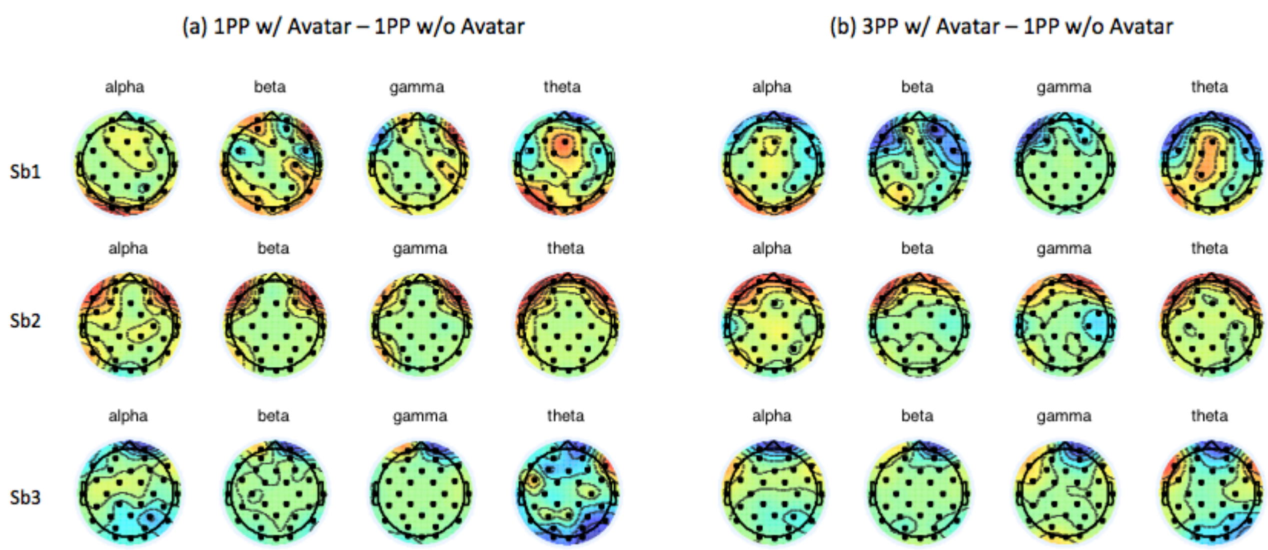

Figure 3. EEG power comparison for each subject: (a) EEG power subtraction between *1PP with avatar* and *1PP without avatar*, (b) EEG power subtraction between *3PP with avatar* and *1PP without avatar*.

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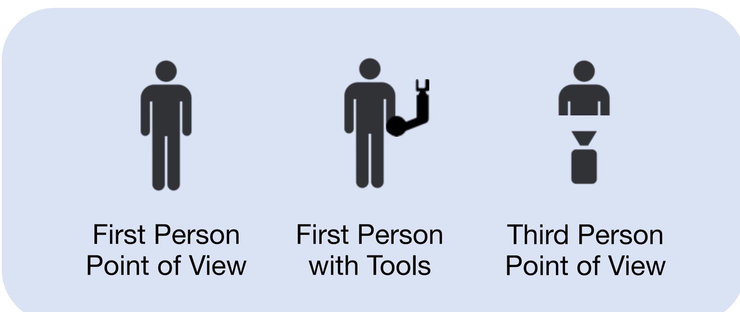
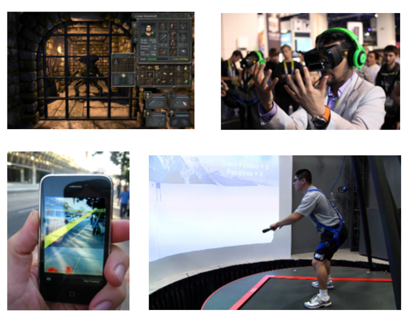
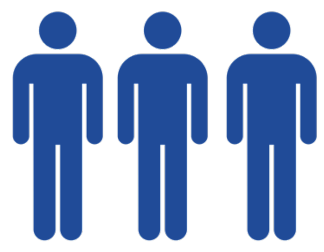
Types of Avatar in 3D Virtual Space



3D Virtual Space Applications

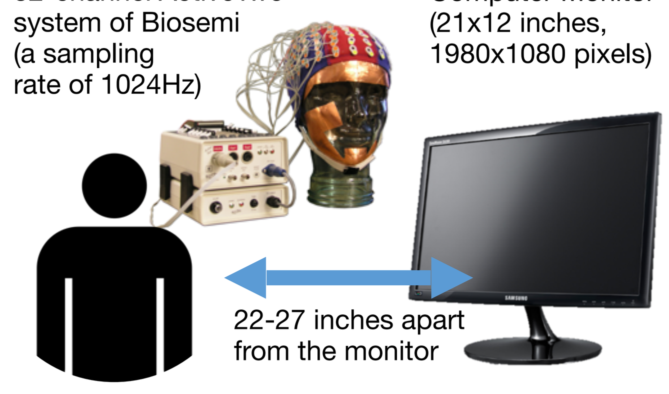


Study Design

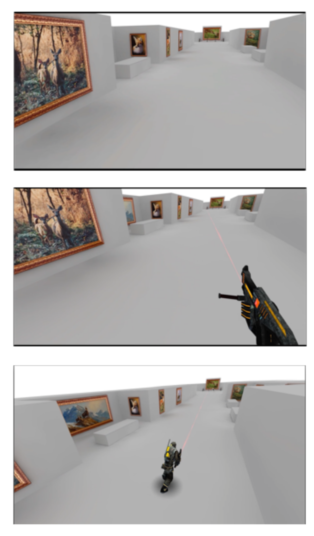


Participants
1 Male and 2 Females
(age=20-24 years)

Experiment Environments



Video Clips
3 sequences of an art gallery in different perspectives with a frame rate of 24 Hz



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Results

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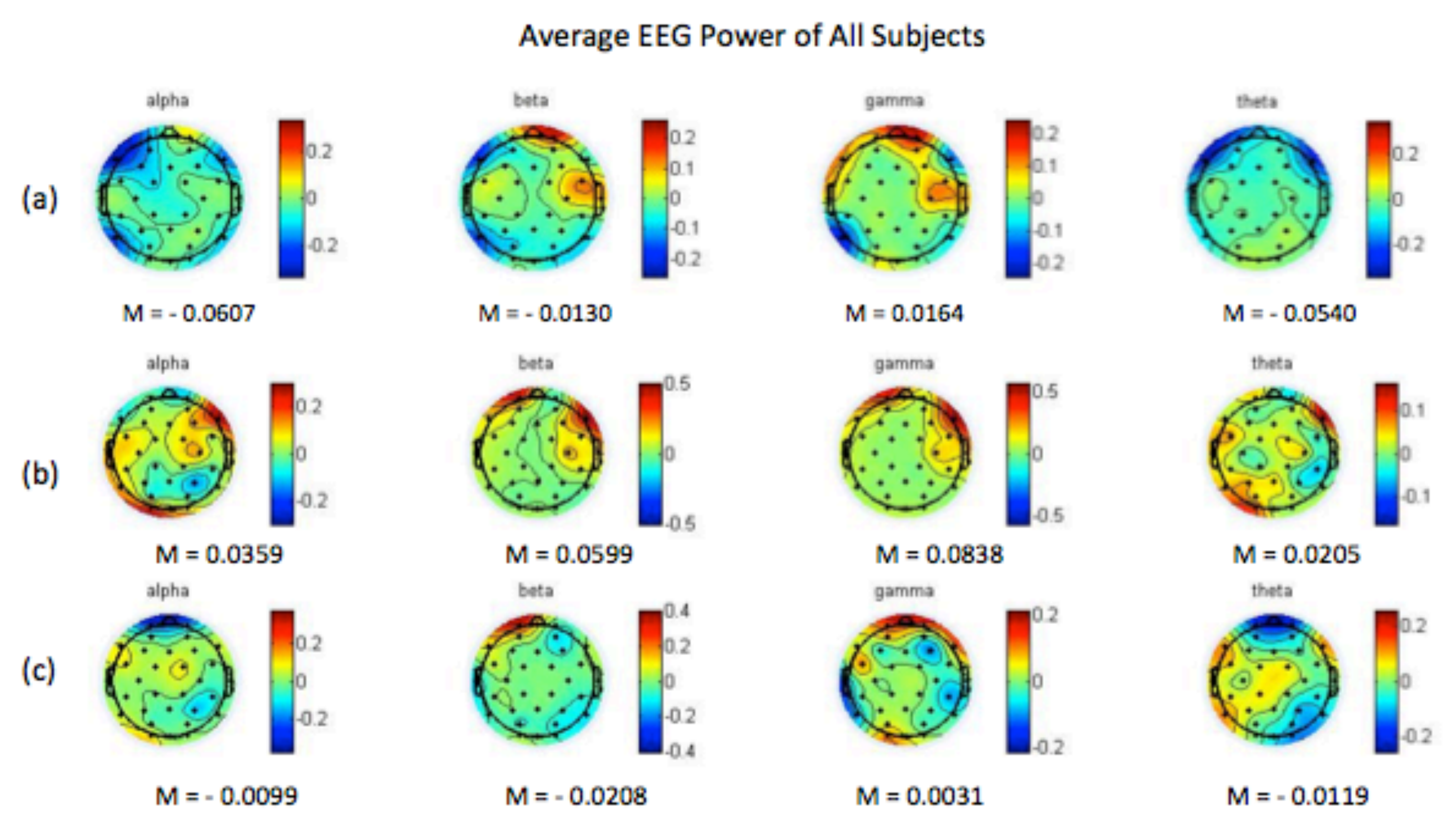

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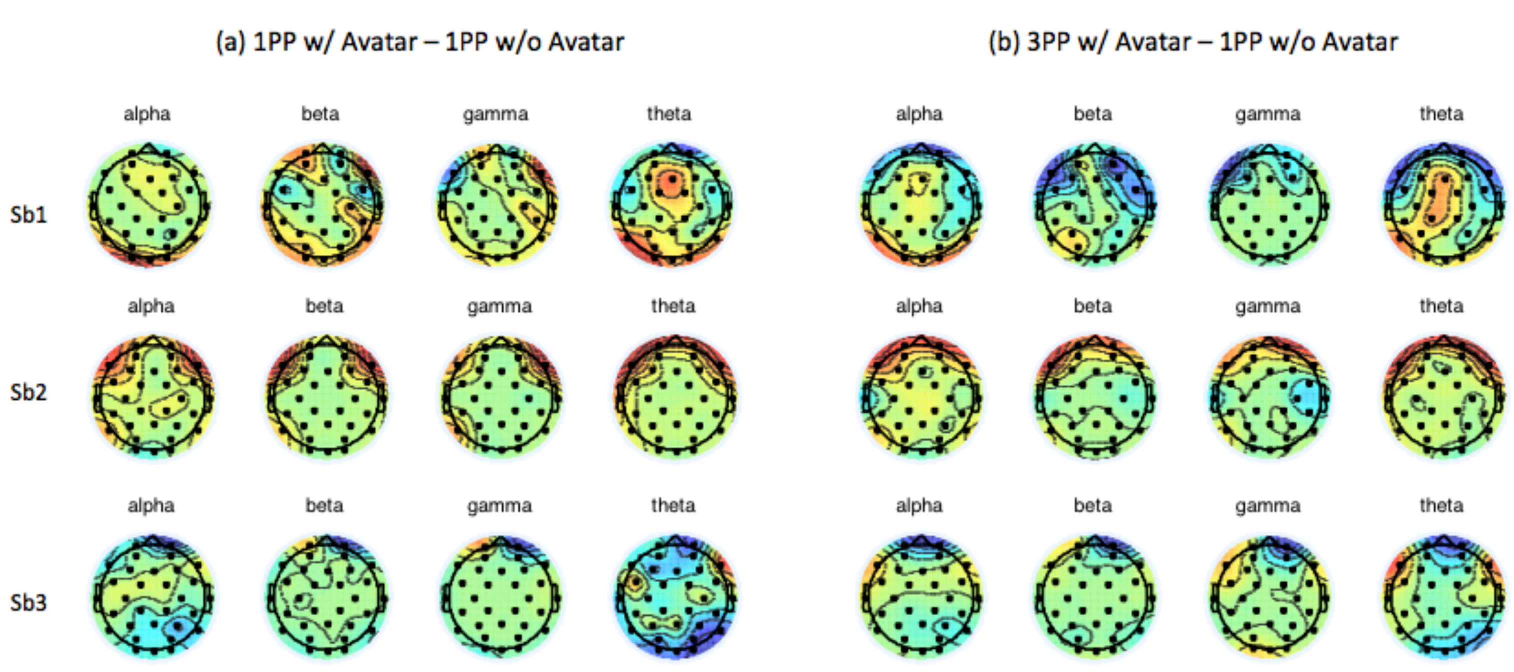

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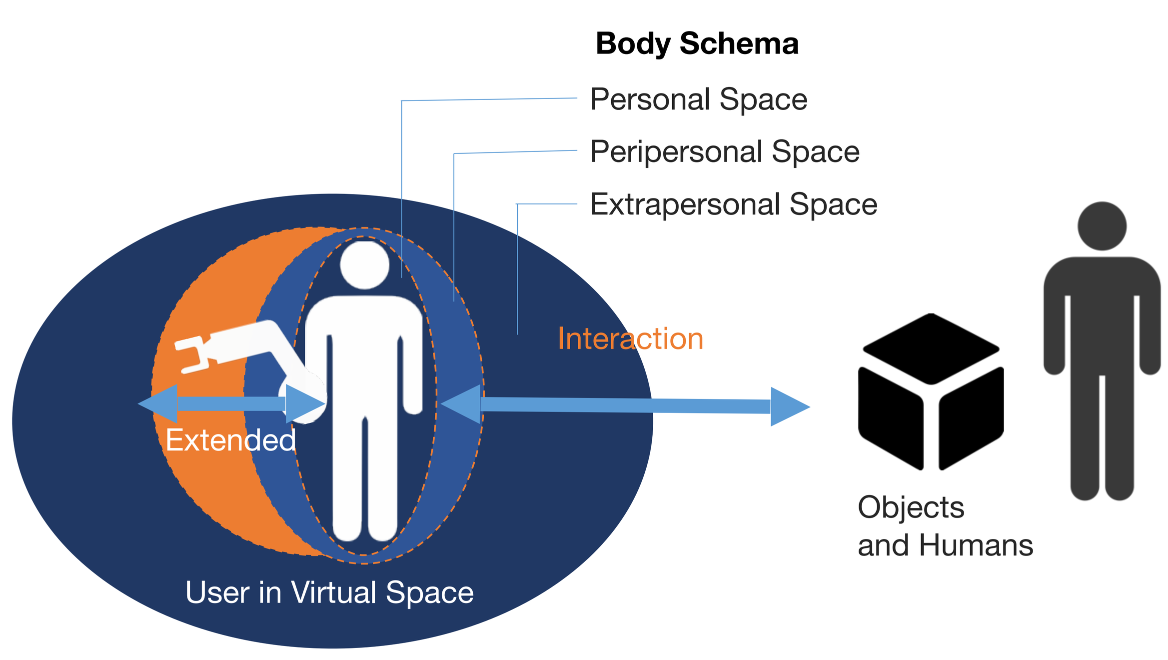

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