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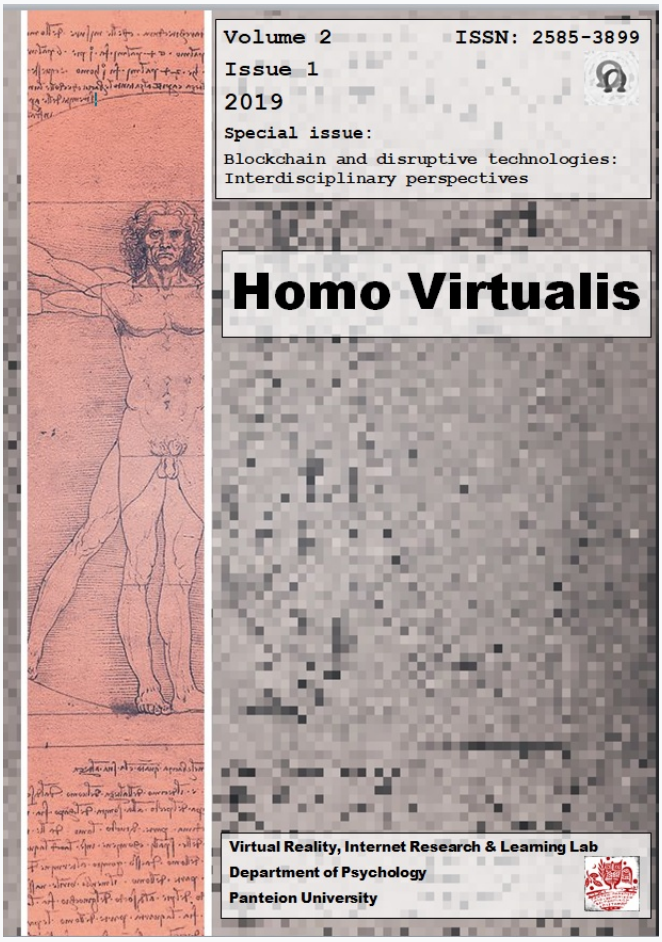

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Assisted spatial navigation: new directions

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Abstract: Blockchain technology brings new possibilities in assisted spatial navigation. Decentralized map building enables collaboration between users around the world, while providing researchers with a common reference map for extending the capabilities of navigational systems towards more intuitive and accurate landmark navigation assistance. Research on landmark navigation has been mainly focused on the visual characteristics of landmarks. Human behavior, however, has systematically been shown to be enhanced in the presence of multisensory unified events. We propose, therefore, the enhancement of spatial assisted navigation by utilizing landmarks that are multisensory and semantically congruent. Further, our research will provide insights in terms of the auditory parameters that could be combined with a given visual landmark, so as to facilitate landmark retrieval algorithms and user satisfaction during assisted spatial navigation.

Keywords: *assisted spatial navigation, audiovisual landmarks, blockchain technology, multisensory, virtual city*

Introduction: Landmark assisted navigation

The use of distance-to-turn verbal information (e.g., “in 55 metres turn left”) might be a widespread technique in spatial navigation systems, yet not the most reliable and easy to understand navigation method (May & Ross, 2006). The available environmental landmarks (e.g., distinctive buildings, stores, streets, or signs) are widely accepted as the key targets to navigation, helping navigators to orient themselves, estimate distances in relation to the landmarks’ position, and create a mental representation of the environment (Kitchin, 1994). Distance instructions have, thus, been enhanced with landmark information (e.g., “walk straight, pass theatre, walk to crossing”) demonstrating that this type of information is as effective as distance-to-turn information (Rehrl at al. 2010), more intuitive for the users, and less distractive during driving (Drager & Koller, 2012).

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Landmark navigation, therefore, is an ideal field for investigating how one could improve everyday life in terms of creating more user-friendly navigational systems. But, should we continue to rely only on the visual characteristics of the available environmental landmarks during navigation? It has been supported that the human brain mostly relies on the visual information present in the environment to navigate in space (Ekstrom, 2015; Foo et al., 2005). Given, however, the load on the visual system (e.g., while driving a large number of visual indicators are used to inform the driver of a given situation; e.g., gas level, temperature indicator) and the multisensory events around us, it remains an open question how cues from other modalities (e.g., audition) that are relevant to a given visual landmark could further improve spatial navigation.

Multisensory perception in spatial navigation

According to the theory of multisensory perception, perception is enhanced by integrating information originating from different sensory modalities (e.g., vision, audition, and olfaction) into a unified percept (Stein & Meredith, 1993). Moreover, research has shown that congruent audiovisual landmarks enhance wayfinding performance in maze environments by reducing the distance travelled and decreasing the time travelled (e.g., Werkhoven, van Erp, & Philippi, 2014). Although it seems that auditory stimulation enhances visually presented cues mostly when the two are somehow correlated (e.g., Ardito et al., 2007), it is not yet clear how the audiovisual landmarks would affect different aspects of navigation such as wayfinding and spatial memory navigation in a complex city environment. The limited available research renders the investigation of how multisensory stimulation affects the navigation process necessary.

In our study, therefore, the effect of landmark modality on spatial navigation will be addressed by using, for the first time, a three-dimensional virtual city environment with realistic visually or audiovisually presented landmarks. The audiovisual landmarks will be congruent images and sounds that fit the city context (such as the view of a house with a garden and the sound of an automatic watering system or a visual café with the sounds of crowded conversations) and are located on the decision points of the environment. The participants in our study will perform a wayfinding task (i.e., find a specific landmark in the city environment) and two spatial memory tasks such as landmark recall and landmark localization task (Werkhoven et al., 2014). We expect better overall performance in the audiovisual landmark presentation across the different tasks based on the expected cognitive advantage due to the multisensory processing of the incoming information. Our research will contribute to better understanding the role of multisensory integration in spatial navigation, as well as to how the landmarks' auditory parameters could define the extraction of reliable landmarks from the editable OpenStreetMap (OSM). That is, if multisensory landmark presentation shows better navigation performance, then OSM tags of landmarks should be modified accordingly so as to include a mix of visual and auditory information.

Conclusion

To sum up, decentralized and consensus-driven map building from users around the world (OSM and FOAM-The consensus driven map of the world; Wright, 2018) offers a common reference point to navigation researchers and creates new opportunities in the design of

intuitive landmark-based navigation systems. A main problem in the research and design of landmark spatial assistance is the difficulty to determine the usefulness of the landmarks (Krukar et al., 2017). The OSM and FOAM maps enable the researchers to create, implement, and compare algorithms that extract information regarding the usefulness of each environmental cue as a potential landmark (e.g., landmarks' saliency, position, and distance to the navigator) depending on the goals of the navigator and the provided tags by the users (e.g., Gracer, 2017; Rousell et al., 2015; Rousell & Zipf, 2017). The critical point on the extraction of a useful landmark is to take into consideration the parameters of human cognition and not to focus only on the visual landmark information, as has traditionally been done. Our research, therefore, aims to further investigate spatial navigation as a multisensory process in a virtual city environment and aims to extend the current parameters of a given landmark used on a consensus-driven map towards more sensory rich solutions.

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