Continuous vs. Discontinuous (Teleport) Locomotion in VR: How Implications can Provide both Benefits and Disadvantages

Bernhard E. Riecke*
School of Interactive Arts and Technology
Simon Fraser University, Canada

Daniel Zielasko†
Human-Computer Interaction
University of Trier, Germany

Abstract

In this short paper we provide a comparative overview of the implications of using continuous vs. discontinuous (teleport) locomotion methods in VR, and argue how many of these implications can provide both benefits and disadvantages depending on the overall goal, desired user experiences, application scenario/context, as well as individual preferences and one's propensity for cybersickness.

1 Introduction and Motivation

Since VR has become increasingly more powerful, affordable, accessible, and easy to use over the past decades, there has been an impressive amount of new development and innovation on how to best move through virtual spaces. Amongst these locomotion metaphors, teleporting has become increasingly popular for a wide range of applications. Many factors might have contributed to this, including the ease of implementation, its convenience to the user, and elegance. One of the main advantages of teleporting that is often put forth, however, is it's proven ability to reduce cybersickness, which is arguably still the most common and dreaded adverse side effect of VR, especially for controller-based continuous locomotion methods [5, 6]. Instead of directly discussing the advantages and disadvantages of continuous vs. discontinuous locomotion (as has been done in excellent prior work incl. [6]), in this position paper we attempt to relate and derive them more directly from the main properties of continuous vs. discontinuous locomotion. That is, we aim to work towards a more systematic classification and discussion of the relationship between (dis)advantages and underlying causes. Following, we will use this to argue how these core properties have often very clear effects and implications, but that these can turn out to be (or be utilized as) both beneficial or detrimental depending on one's goal, desired user experiences, individual preferences, or application scenario/context.

To provide a compact and clear structure and juxtaposition of continuous vs. discontinuous locomotion and potential benefits and disadvantages, we decided to use a tabular comparison in Table 1, followed by a brief general discussion. Direct implications are indicated by a " $\rightarrow$ ", and potential advantages and disadvantages are labeled as " + " and " - ", respectively.

2 Discussion and Conclusions

We hope that our analysis illustrated how the various properties of continuous vs. discontinuous locomotion methods can have specific implications that are not necessarily always "good" or "bad", but can often be utilized both as an advantage or a disadvantage – depending on the specific goal (e.g., journey vs. target oriented), desired user experience, individual preference, or application-specific context and scenario. For example, the lack of any self-motion cues for teleportation implies a lack of any direct dynamic sensory cue conflict. On the one hand, this can help reduce the cross-sensory conflict between audiovisual cues indicating self-motion and proprioceptive cues indicating stationarity when users can't physically move, thus reducing cybersickness [6]. On the other hand, the same lack of any self-motion perception and continuous transition between the original end final position takes away any opportunity for path integration, and relies solely on static audiovisual cues to indicate the new location. We hypothesize that this could potentially be perceived as less natural, embodied, and contribute to breaks in presence or immersion.

Note that any locomotion method that involves teleportation does not really have any real-world equivalent (besides science-fiction depictions of teleporters). On the one hand, this could be utilized to an advantage, as users don't have any corresponding real-world experiences that need to be "matched" as is the case for most continuous locomotion methods. E.g., it can be quite challenging to provide a realistic experience of riding a bicycle as users will compare it to their real-world experiences, whereas nobody really knows how teleporting should "feel like". On the other hand, as teleporting does not have any real-world equivalent, it might be perceived as more artificial, and have lower ecological validity. Again, depending on one's overall goal, this might be detrimental (e.g., when trying to mimic a real-world situation such as training or architectural planning) or potentially advantageous (e.g., when simulating a futuristic scenario or super-natural experience). This context-dependency was also suggested in a recent study [1], where adding teleports (iterative jumps) was perceived as more disturbing when the locomotion interface was more embodied (leaning-based vs. controller) and participants were more immersed, such that teleporting seems to have triggered a stronger and more disturbing break in presence/immersion.

Furthermore, teleporting provides no experience of the in-between locations and journey itself, and it is conceivable that this might negatively affect our mental spatial representation and its continuity and connectedness.

*e-mail: b_r@sfu.ca
†e-mail: zielasko@uni-trier.de

References

[1] A. Adhikari, D. Zielasko, M. v. d. Heyde, E. Kruijff, A. Bretin, and B. E. Riecke. Integrating Continuous and Teleporting VR Locomotion into a Seamless "HyperJump" Paradigm. In *IEEE VR Workshop on Finding a way forward in VR locomotion*, pp. 1–2. Lisbon, Portugal, 2021.

[2] J. Bhandari, P. MacNeilage, and E. Folmer. Teleportation without spatial disorientation using optical flow cues. In *Graphics Interface Conference*, GI '18, p. 162–167, 2018. doi: 10.20380/GI2018.22

[3] Y. Farmani and R. J. Teather. Evaluating discrete viewpoint control to reduce cybersickness in virtual reality. *Virtual Reality*, Jan. 2020. doi: 10.1007/s10055-020-00425-x

[4] B. E. Riecke, M. V. D. Heyde, and H. H. Bülthoff. Visual cues can be sufficient for triggering automatic, reflexlike spatial updating. *ACM Transactions on Applied Perception*, 2005. doi: 10.1145/1077399.1077401

[5] T. Weissker, A. Kunert, B. Frohlich, and A. Kulik. Spatial Updating and Simulator Sickness During Steering and Jumping in Immersive Virtual Environments. In *2018 IEEE VR)*, pp. 97–104. Reutlingen, Mar. 2018. doi: 10.1109/VR.2018.8446620

[6] M. A. Zayer, P. MacNeilage, and E. Folmer. Virtual Locomotion: a Survey. *IEEE Transactions on Visualization and Computer Graphics*, pp. 1–1, 2018. doi: 10.1109/TVCG.2018.2887379

Riecke, B. E., & Zielasko, D. (2021). Continuous vs. Discontinuous (Teleport) Locomotion in VR: How Implications can Provide both Benefits and Disadvantages (pp. 373–374). Presented at the IEEE VR Workshop on Finding a way forward in VR locomotion, Lisbon, Portugal: IEEE. doi:10.1109/VRW52623.2021.00075

Table 1: Categorization of continuous vs. discontinuous locomotion.

Category	Continuous locomotion (from real walking w/ HMD to controller-based)	Teleporting (e.g., controlled by aiming the controller at the target location)
Movement velocity & time	Limited **finite** movement velocity → it takes time to get anywhere - Can be/appear time consuming, boring, annoying, inefficient, especially when journey itself is not interesting or the goal + More time to experience/enjoy and process the journey and transition to the new location, and prepare for what's ahead + If the "journey matters" it might feel more valuable *(e.g,, strolling through an interesting environment)*	**Instantaneous** teleportation, so velocity not defined → you can get anywhere instantaneous (as long as you can indicate where you'd like to go directly, or do multiple jumps) → no/minimal time needed to go anywhere + It's fast and the dream of many frequent travelers: spending time only on the journey parts you want to see and "skipping" the rest - There's no time to experience the journey, transition, mental/spatial context-switching, or prepare for what's next - It often takes time to mentally switch, and to re-orient and update one's egocentric representation, although it can happen quite rapidly for well-known environments [4].
Accuracy	+ Potentially very **high accuracy**, as continuous adjustment possible during locomotion - Higher accuracy can require more time (slower locomotion) [Note: Hybrids like dash [2] or iterative teleporting [1,3,5] can reduce travel times]	**Accuracy-distance tradeoff** + higher accuracy for shorter distances (and more precise aiming) - reduced accuracy for longer jumps
Audiovisual self-motion cues & sensory conflict	**Continuous optic flow** (or tactile or auditory flow) → **vection** possible (typically increased vection for more embodied locomotion and cross-sensory consistency) + -Can feel more naturalistic, embodied, real-life-like as real world physical self-motion is accompanied by perceived self-motion - Mismatching self-motion cues (e.g., for controller-based locomotion) and/or harsh accelerations/decelerations etc. can reduce realism and contribute to **cybersickness**	**No optic flow**, i.e., no visual (or other) self-motion cues at all → **No vection** aka perceived self-motion, as there is none → **No dynamic sensory conflict** between different cues indicating self-motion vs stationarity (as all indicate stationarity) + No cues promoting cybersickness - Lacking natural self-motion cues, so potentially perceived as less naturalistic (in the sense that there's no real-world equivalent experience, even though users can get used to teleporting), embodied, ecologically valid, and "real"
Self-motion cues beyond audio-visual	Ample **natural proprioceptive cues** for embodied locomotion metaphors like walking, although more limited for controller-based, with leaning-based, WIP etc. in-between + Potentially **increased embodiment, naturalism and engagement**	**No proprioceptive self-motion cues** (apart from using controller) - Potentially **reduced sense of embodiment , naturalism, and engagement**
Path integration (vs. piloting)	Continuous self-motion cues → p**ath integration possible** + Can improve spatial orientation and prevent disorientation, as no re-orientation (recovering of disorientation) needed + Can tap into (automated) continuous spatial updating, which is known to have low cognitive load as it is largely automated or even obligatory (e.g., for walking).	No self-motion cues → **path integration impossible** → has to rely on other means to recovering orientation and remaining spatially oriented, such as piloting (landmark-based navigation) and/or on user's prediction/anticipation of future location.
Locomotion control	User **indicates current movement direction/velocity/ acceleration** (e.g., for controller- or leaning-based locomotion), or proprioceptive control for walking	User **indicates final target position** (and orientation sometimes, although often not changed), typically by direct or parabola pointing. "Path" doesn't matter and is not defined.
Effort	Depending on locomotion metaphor can take considerable effort, e.g, when continuously moving (e.g., walking) for extended path, or having a challenging path (platformer, obstacles...) → **More exhausting, cognitively or physically demanding, requiring sustained attention** - can be undesired if users just want to get somewhere easily, e.g, when effort/exertion is not one of the goals + Similar to walking/hiking/biking: one has more time to experience/enjoy/perceive the environment and journey + Effort might promote feeling of accomplishment and achievement ("If it's free it isn't worth anything") + High effort can be desirable e.g., for exergames	**Minimal/no effort**, as one only needs to indicate desired target position (and orientation), + Can be convenient, easy, effortless, practical + Can provide "instant gratification" - Reduced sense of accomplishment, effort, value (e.g., of hiking up mountain or completing challenging journey) - By being so convenient it can reduce desire to move ourselves, exacerbating "couch potato" syndrome
Presence & immersion	Spatiotemporal continuity and embodiment might **enhance presence/immersion**	Spatiotemporal discontinuity and reduced embodiment might **interfere with, or induce breaks in, presence/immersion**