Feeling Your Way Home: Body-Based Locomotion vs. Joystick Steering for Path Integration in VR

A within-subjects pilot study in Unity VR on proprioception, spatial updating, and navigation

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Abstract

In a seated VR triangle-completion pilot (n = 4), arm-swing walking-in-place gave smaller homing errors than joystick steering (7.8 vs. 9.9 m). The joystick condition always came first, yet with each first joystick trial treated as practice, arm swing stayed ahead for three participants and level for the fourth. Returns barely depended on the triangle, and participants reported counting swings, seconds and snap turns, suggesting arm swing may help by making distance countable.

Keywords: virtual reality, locomotion, walking-in-place, triangle completion

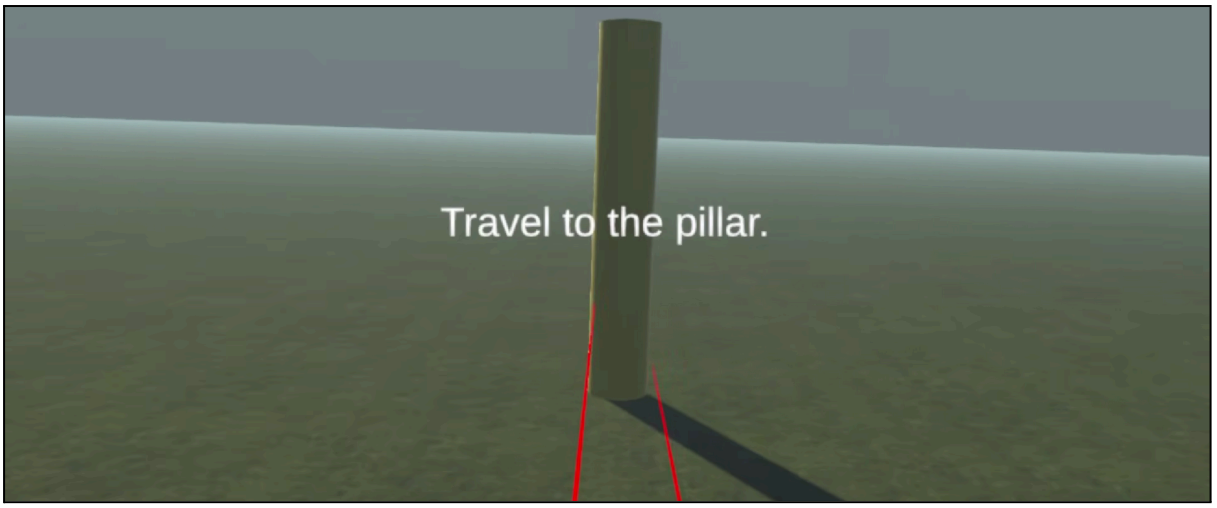


Figure 1: Screenshot of the triangle completion task in Unity.

1 INTRODUCTION

Getting lost can be an early sign of Alzheimer's disease. Unlike healthy older adults, people with early Alzheimer's disease become disoriented in familiar places, and path integration, which updates the cognitive map from self-motion, is impaired already in prodromal stages (Coughlan et al., 2018). Earlier changes are often subjective and escape standard tests (Coughlan et al., 2018), whereas virtual wayfinding is sensitive to preclinical Alzheimer's disease (Allison et al., 2016). As the disease mainly affects older adults (Alzheimer's Association, n.d.), such tests should suit them.

VR offers controlled wayfinding tasks, such as triangle completion, in which a person returns directly to an unmarked start after two legs (Dorado et al., 2019; Kearns et al., 2002). However, how users travel may change what is measured. From an embodied cognition perspective, spatial updating draws on bodily movement: in VR, optic flow without proprioception did not update heading effectively (Klatzky et al., 1998), and vision and proprioception contribute about equally to path integration (Chrastil et al., 2019). Joystick steering provides optic flow only, whereas arm-swing walking-in-place adds proprioceptive and motor cues. This pilot therefore asks whether arm swing gives more accurate homing than joystick steering (RQ1), and whether accuracy improves from block 1 to block 2 (RQ2). The long-term goal is a VR navigation task that could reveal early signs of Alzheimer's disease.

2 RELATED WORK

With a seated joystick, people homed from optic flow, but gave similar responses regardless of triangle shape, whereas active walking made repeated responses less variable (Kearns et al., 2002). Similarly, optic flow alone is enough for homing without landmarks, but homing distances are biased towards the mean (Riecke et al., 2002). Moreover, walking-in-place ranks between real walking and flying (Usoh et al., 1999), offering body cues without physical walking.

3 DESIGN AND IMPLEMENTATION

The prototype is a Unity 6000.3.23f1 scene (XR Interaction Toolkit) with a Meta Quest 1. The participants sat partly because falls are frequent in Alzheimer's disease (Kato-Narita & Radanovic, 2009), and sitting reduces imbalance and fatigue compared with standing (Zielasko & Riecke, 2021).

The Unity scene shows a large grass field with distant fog that hides any edge or horizon, giving optic flow without landmarks, which would otherwise dominate homing direction (Zhao & Warren, 2015). Yellow pillars (Figure 1) mark each waypoint in turn and vanish within 0.75 m; participants then return unguided and press the trigger at the believed start, without feedback.

In Bowman et al.'s (1997) taxonomy, both techniques use gaze-directed steering at a constant 1.5 m/s and differ only in input condition: pushing the left stick, or swinging both controllers vertically in opposite directions faster than 0.4 m/s. This threshold, adapted from 0.2 m/s in prior work (Hussain et al., 2026), was refined in pilot testing to give continuous rather than burst-like movement. Both use the XR Interaction Toolkit's default 45° snap turning plus head rotation. Matching speed and turning equalises visual cues, but separates travel from swing effort. Both scripts stayed active, but participants used only the instructed input.

4 METHOD

Four cohort students with varied VR experience and sense of direction took part (Table A1). After giving consent, each answered a short background interview, then completed both techniques, each with 30 s of practice and two blocks of four triangles (Table A2), and finally gave a short interview about strategy, movement feel and technique preference.

Homing error is defined as the distance from stopping point to start, while angular error is the absolute angle at waypoint 2 between directions to start and stopping point. Additionally, one FMS discomfort score (0 - 20) was taken during a break after the joystick condition.

Results are reported per participant alongside interviews. One exploratory exact Wilcoxon test compares techniques (minimum possible p = .125 with n = 4), and response distance is regressed on correct distance to test the bias towards the mean. In addition, a sensitivity check excluded each first joystick trial and one accidental P1 confirmation.

5 FINDINGS

Speed was matched: median head speed while moving was 1.40 m/s throughout.

Participant	Homing error J / AS (m)	Angular error J / AS (°)	Return time J / AS (s)	FMS (0 - 20)
P1	10.2 / 5.9	76 / 40	11.6 / 10.3	0
P2	13.6 / 11.2	74 / 78	21.4 / 21.2	0
P3	9.8 / 8.1	63 / 47	20.7 / 12.9	10
P4	6.1 / 5.9	36 / 42	10.3 / 9.8	1

Table 1: *Per-participant means (J = joystick, AS = arm swing).*

Table 1 lists each participant's mean errors, return times and discomfort score.

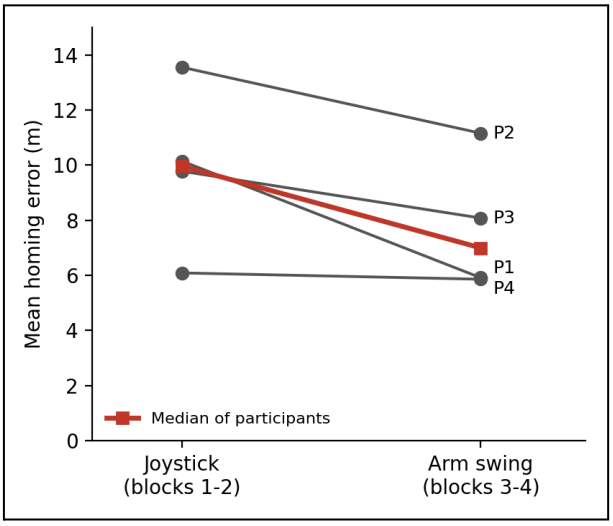


Figure 2: *Mean homing error per participant.*

Figure 2 draws one line per participant: every line slopes downwards from joystick to arm swing, steeply for P1 but almost flat for P4.

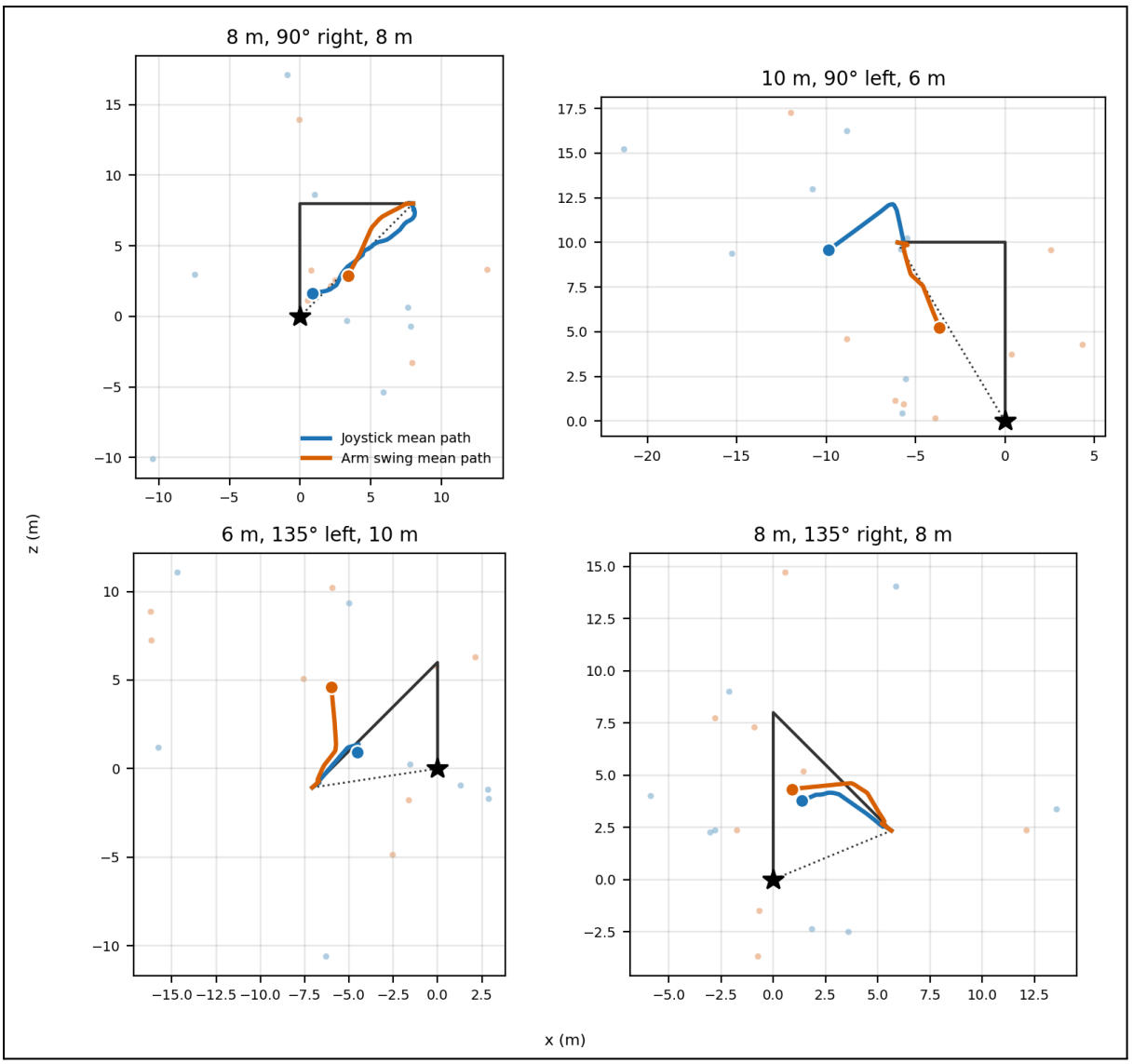


Figure 3: *Return paths of all 64 trials: mean path and endpoint per technique; start = star.*

Figure 3 pools all returns per triangle: mean paths head roughly homewards, yet end 1.8 to 13.7 m from the start, with neither technique consistently closer. However, arm-swing endpoints scatter less (7.3 vs. 8.7 m), suggesting more consistent rather than better-aimed returns. Overall, homing error averaged 9.9 m (joystick) and 7.8 m (arm swing). All four were lower with arm swing (median difference -2.05 m; exact Wilcoxon p = .125), though P4's difference fell to -0.01 m after exclusions. Angular error, however, was lower with arm swing for only two. Furthermore, returns averaged 9.3 m regardless of the triangle (slopes 0.10 and 0.07).

P1 (experienced, sense of direction 7) gained most from arm swing yet preferred the joystick, whose speed felt matched: arm swing was “kind of fake.” In contrast, P2 (sense of direction 3) had the largest errors and preferred arm swing, because swings were easier to count. P3 (first VR use) improved within both techniques, began reasoning that the path “is a triangle”, and reported exhaustion (FMS 10). Finally, P4 had the smallest errors and found the techniques “not that different”. All four named snap turning hardest, and P2 - P4 reported low confidence.

6 DISCUSSION

Regarding RQ1, arm swing lowered homing error for everyone, only marginally for P4 but strongly for P1, whereas angular error did not follow. Regarding RQ2, error fell from block 1 to block 2 in seven of eight participant-technique pairs (Table A3). As the joystick condition always came first, practice may explain part of the arm-swing advantage, though P3’s fatigue points the other way.

Moreover, participants counted swings, steps or seconds, which is the timing strategy that Kearns et al. (2002) suggested for joystick homing. Since speed was constant, counts track distance; thus, arm swing may help by making distance countable rather than through proprioception. Furthermore, the near-flat slopes are an extreme form of the bias towards the mean (Riecke et al., 2002).

7 LIMITATIONS AND FUTURE WORK

Four cohort peers cannot represent older adults; moreover, snap turning may drive angular error more than technique. In addition, counterbalancing was not set, so everyone used the joystick first and saw the same triangle order, confounding learning with technique. Furthermore, arm swing only switched movement on or off rather than scaling with swing speed, and discomfort was measured only after the joystick condition. A larger study should therefore alternate which technique comes first across participants, add an uncounted practice trial for each technique, measure discomfort after each technique and replace snap turning with a swivel chair, so seated participants can turn physically.

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Appendix

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A) Project Resources

GitLab Repository

- https://gitlab.utwente.nl/s3980405/mgetxr-final

Video showcase of the VR unity experiment

- https://youtu.be/YU1eHaRrh0U

Demo day presentation slideshow

- https://docs.google.com/presentation/d/1nT3fsuuQzApitolv6Zm3vGwccxHz9K-1JIlwSV571n0/edit?usp=sharing

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B) AI Use Reflection

I followed the AI-assisted path throughout this project. During development, AI helped me write the initial Unity scripts, which I then adapted and extended by hand; in addition, I reused the XR Origin setup, the XR Interaction Toolkit and its snap turn technique from my A6 assignment.

Beyond writing code, I mostly used Claude as a talking partner for specific questions. When I did not fully understand something, such as how the exact p-value is calculated with only four participants, what a sensitivity check shows, or the difference between consistent and accurate responses, I asked it to explain step by step. This helped me understand my own analysis well enough to explain and defend it, rather than just reporting numbers.

However, I found Claude much stronger at grammar, coding and explaining concepts than at research. AI tools can confidently invent or misstate research papers, so I could not trust a source simply because it was suggested.

Therefore, Claude helped with grammar and with fine-tuning my writing, and I used it to check whether the report met the course requirements. Overall, AI made the project faster and helped me understand my own results better, but every claim in the report remained my responsibility.

C) Result tables

Participant	Prior VR use	Video games (h/week)	Sense of direction (1-7)	Motion sickness
P1	Regular during an earlier VR project, rarely since	~8 before Master's, now 0	7	Car only, not VR
P2	Two times before this study	~10 at peak, currently little	3	None
P3	None before this project	0	3	None
P4	Once or twice, for this course	0	4.5	Occasional car sickness

Table A1: *Participant background from the pre-interviews.*

Leg 1 (m)	Turn at waypoint 1	Leg 2 (m)	Correct homing distance (m)
8	90° right	8	11.31
10	90° left	6	11.66
6	135° left	10	7.15
8	135° right	8	6.12

Table A2: *Triangle set; each triangle once per block in shuffled order. Correct homing distance is from waypoint 2 to the start.*

Participant	Joystick block 1 → 2 (m)	Arm swing block 1 → 2 (m)
P1	7.5 → 12.8	7.5 → 4.4
P2	14.3 → 12.8	11.3 → 11.0
P3	11.8 → 7.8	9.1 → 7.1
P4	7.4 → 4.8	6.3 → 5.4

Table A3: *Mean homing error (m) per block. Error fell from block 1 to 2 in seven of eight participant-technique pairs; only P1's joystick error rose.*

D) Consent form

- Link to consent form: https://forms.gle/aQfNBEdJvZkdcTPq6

Consent form: Feeling Your Way Home

MGETXR VR Research Project

About the study

This study compares two ways of travelling in virtual reality, swinging your arms and using a joystick, and asks how well you can find your way back to a starting point. It is a small student project for the course MGETXR at the University of Twente. You will wear a VR headset and complete short travel tasks while seated, then answer a few interview questions. The whole session takes about 20 minutes.

What data is collected

- Before the session, four short questions will be asked about prior experience and self-assesment.
- During the VR tasks, the computer logs the position of the headset over time, how long each trial takes, how far you travel, and how far your answer is from the true starting point.
- After each block of trials, you give one discomfort score from 0 to 20.
- The interview is audio recorded and transcribed. The recording will be deleted on the 1st of December.
- Your data is stored under a participant ID, not your name. This consent form is the only place with your name, and it is kept separately from the VR and interview data. No health data is collected. The data is only used for this course project and its report.

Possible dizziness and discomfort

VR can cause temporary symptoms such as dizziness, nausea, headache, eye strain or a feeling of disorientation. These are more likely when the virtual movement does not match what your body feels, which is the case here, because you travel while sitting still. Most people notice little or nothing, and symptoms usually pass within a few minutes after the headset is off. Please do not take part if you feel unwell today or know that VR or strong motion sickness is a problem for you.

Your rights

Taking part is voluntary. You can stop at any time without giving a reason, and you can ask for a break at any point. There are also short breaks between blocks. If you feel any discomfort, tell the researcher right away and the session will be paused or ended. After the session, please sit and rest for a few minutes before leaving, and avoid cycling or driving until you feel completely well.

Contact

Clara Holst, c.holst@student.utwente.nl. Supervisor: Marcello Gómez Maureira.

Consent: Please check all boxes*

- I agree that the interviews can be audio recorded and transcribed
- I know my participation is voluntary, and I can stop at any time without giving a reason
- I understand that my data is only used for this course project and report
- I agree to take part in this study

Write your name as a digital signature*

E) Interview structure

Consent form link: https://forms.gle/aQfNBEdJvZkdcTPq6

Explanation of trials

- Homing task: Triangle completion
- Joystick and armswing
- 8 trials of each technique, with an optional break between every 4 trials
- In total 16 trials
- After 8 trials let me know, when it asks for the next technique: arm swing

Before the session

1. Have you used VR before? (never / a few times / regularly)
2. Roughly how many hours per week do you play games?
3. How would you rate your sense of direction, from 1 (poor) to 7 (excellent)?
4. Do you have any dizziness or motion sickness issues? (yes / no)

After each technique:

- On a scale from 0 to 20, where 0 is no sickness at all and 20 is feeling sick, how do you feel right now?
    - P1: 13:35 - 13:55 = 0 sickness
        - ID 134449
    - P2: 14:00 - 14:20 = 0 sickness
        - ID 140547
    - P3: 14:39 - 14:59 = 10 sickness (specifics: exhausted, tired, fatigued)
        - ID 143919
    - P4: 15:40 - 16:00 = 1 sickness (feeling slightly uncomfortable)
        - ID 154552

After the session

1. When you had to return to the start, how did you figure out where it was?
    - Did your strategy differ between arm-swinging and joystick?
2. How did moving feel in each technique?
    - Did you feel like you were actually travelling through the space?
3. How easy or hard was each technique to use?
    - Joystick, snap turn, head turn, arm-swing etc.
4. Which technique made it easier to know where you were relative to the start?
5. How sure were you of your answers (if you found your way home)?
6. Do you have anything else that you would like to share about the experience?

F) Transcribed interviews

p[n] before: before participating in the VR experiment
p[n] after: after participating in the VR experiment

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p1 before:

Okay, so the first thing, have you ever used VR before? Yeah. And then from like a scale from never, a few times, regularly, how often would you say you use VR? Regularly, I worked on like a VR project, so at the time I used it a lot, but after I finished the project, it's been a while since I used it, so yeah. So maybe in between, like between 1 to 10, 5 can be.

Yeah, okay. What about generally video games? How many hours would you say you spend on that, maybe a week, a month? Oh, before I started Master's, I used to play video games quite often, like Minecraft. Yeah, maybe like eight hours a week.

And what about now? Now it's zero. Busy with studying. Makes sense.

Okay, how would you rate your sense of direction, like your wayfinding skills? I'm quite good at it, yes. From 1 to 7, where 7 is good? 7, I think. Even though I go somewhere really unknown, It’s quite easy to find the way.

Nice, that's impressive. That's good for my studying. Okay, do you have any dizziness or like motion sickness issues? I have for the car.

Okay, but that's for VR? Not for VR. Okay, that's great. All right, that's, yeah.

p1 after:

Alright, when you had to return to the start, like where you came from, how did you figure out where it was? Did you use any strategy? It's like, so first I tried to use the right rotation, because like a one click is kind of 45 degrees, or I don't know how much degree it is. So like I just like, okay, I move the joystick to the left twice. That means I need to, if I want to go back, I need to move the joystick to the right twice.

Yeah, that makes sense. Is there any different techniques, depending on the joystick and the arm swing? Ah, joystick, it feels more natural, I feel like, because it's quite connected with how much I push the joystick, and the speed of moving in the virtual space. Yeah.

But besides that, like if I move my arms, it feels like I move quite fast, but my speed is quite slow, and then it doesn't feel really smooth. So that's why I feel like, okay, this is kind of fake. Right, yeah, that makes sense.

Did you feel like you were actually moving through the space in both joystick arm swing conditions? At first, moving with arms was more interesting, feeling at first, but after trying multiple times, it doesn't match with my speed, like my real speed. So it's like, no, I like the previous one more, with the joystick. Yeah, okay.

How easy and hard was it to use each technique? So both joystick, the snap turning, turning with your head, and arm swing? Because I'm in the sitting position, so even though I move quite freely, it doesn't feel really smooth, because I want to turn here, but I cannot see the backside fluently. Yeah. But I think rotation, no, rotation was a little bit fake for me, but a translation with a joystick was good, and yeah, the moving arm was interesting, but yeah, it doesn't really feel natural.

Yeah, and for, again, joystick and arm swing, which technique do you think made it easier to find your way home? To find the way home? I think, I don't know, maybe this is a little bit out of scope, but the rotation with the right control was more, it makes a little bit more difficult, at the same time, it makes more easy to find the way, because if you rotate with the joystick, you can also count, okay, how much I time count, but I need to move to two targets, and for the first target, it was quite easy, but after the here, and then if I move toward here again, then I miss the, kind of, okay, how can I, how should I go back, like, the rotation-wise is a little bit difficult. Okay, is there anything else that you would like to share about the experience? I like the arm moving, but maybe it would be nice to match with the speed of arm, like a swing motion, because eventually, I tried to, like, do this at first, but it feels really not natural in the VR space, so what I did was, I could do this, like, it's a little bit technical to make it a little bit, like, okay, this one is more, yeah, more natural in VR, so, yeah. Okay, perfect, thank you.

Nice.

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p2 before:

Have you ever used VR before? Yeah, like two other times. In total? In total, yeah. So in total it's three, including this one. Okay, yeah. And how many hours per week do you usually play video games? Or have you played video games more before? I, as of right now, not really, because of the exam season, but when I used to play my prime I probably would spend about ten hours a week, I would say, maybe more. Okay. How would you rate your sense of direction? From 1 being very poor, very badly, and 7 being excellent sense of direction. In general or in regards to the... In general. In

general? Yeah. I think I can orient myself well. What was the scale again? 1 to 7. 7 is good. I'll just go halfway. I'll probably say like, pessimistic 3. Okay, okay. Yeah. Yeah? It should be much lower. Yeah. And you know, I don't want to hear anything from you. Okay. Do you have any dizziness or motion sickness issues in general? No, not really. Absolutely not. That's good.

p2 after:

Okay, so when you had to return home, how did you figure out where it was? What was your strategy? So I would count the number of steps that I took, the number of strides I took to that pillar, and how many snaps I took to get to the first one, and then the same thing again for the last one, and then reversed the turn in the other direction, in reverse order, and then same number of steps back home. Hypothetically. Yeah, that seems calculated. Was there any difference in the way that you formed your strategy based on the condition, if it was joystick movement or arm swing movement? It was more or less the same, apart from the fact that I probably counted differently.

For the swing, it was more the number of swings I took, but for the joystick, I can't remember of seconds loosely that it took me. Okay. Okay. How did moving feel in each technique? Did you feel like you were actually moving through the virtual space? I think, okay, with the joystick, it felt a bit smoother for me to like walk, but the striding, it was a bit awkward for me.

I don know if it was as responsive as I was imagining it to be or the distance I would move based on the stride How easy or hard was each technique So it could both be arm swing joystick snap turning or turning with your head So the hardest was probably the snap turn because it disordered me trying to figure out how much I would have to do to reverse back home. The joystick was quite smooth. Walking with a stride was not as smooth, but also it wasn't that crazy either. So what technique overall made it easier, do you think, to find your way back home? I would probably say the swing actually, because I could count the number of swings much more Orderly compared to the joystick.

Yeah. How sure were you of your answers?

Is there a scale for this? No, but you can say what... I have no confidence that I got back home in any of them. Maybe two of the trials. Maybe two. But that's when I really locked in. Yeah, yeah. Okay. Is there anything else that you would like to share about the experience? Yeah, thank you. That was it.

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p3 before:

Have you used VR before? And how often? I haven't and yeah. Not at all? No, like before no, like this is the first time because of the project. Okay. How many hours per week do you usually play video games or have played before? Zero. Never? Before zero as well. How would you rate your sense of direction, like wayfinding abilities? 1 is very bad and 7 is very good. In terms of finding your way home? Not using Google Maps? Uh, 3. Okay, fair. If it's in your place. Do you have any dizziness or motion sickness issues? No, in general. No, like car sick? No, no, nothing. Yes.

p3 after:

So when you had to return home to the start, how did you figure out where it was? What was your strategy? I was counting first from my starting point. I was counting the seconds towards the first column that I saw. First, when I was figuring out where the column is actually placed, the first one, I was also counting how many times I am using the controller to go right or left to turn. After that, when I found it, I was counting the seconds towards the first column. And then the first session before there was like the major break. Yeah, this one I was more like calculating because of the turns. If I turned, let's say, five times left, it means that from the same position I would have to turn five times right in order to make the same turn, kind of, to return to my position. But then maybe when I started moving my hands I was kind of I kind of changed my logic about it and I figured out that it is a triangle and I was more like figuring out where when I go to the first column, I was a little bit looking around to see where my starting point was because I I was also able to see the second column. And so to see from the second column to the first place, how should I go, because if it's a triangle it means that I can just go from it, from the second one to the initial point, rather than in the first round I just went back on my steps, like from the second to the first. Yeah, that was basically it. How did moving feel in each technique? Did you feel like you were actually moving through the virtual space? It was... both of them were fine. Maybe with the hands, when I was swinging my hands, maybe it was more realistic definitely because that's how we're used to walk in real life. But I also understand that I not walking and I sitting And so the joysticks also felt good So both were okay Okay. How easy or hard was each technique to use? So both like the joystick, head turning, snap turning, arm swing, all of it.

Yes, but not that. I wouldn't say that any of them were hard.

They were easy to follow.

Maybe the turning was a bit harder than the other ones because they're quite intuitive. But the turning, maybe it was harder because I just needed to remember which direction I'm turning. But the actual action of turning or moving, it was not hard. Which technique made it easier to know where you were relative to the start?

Which technique made it easier to find your way home? Joystick or arm swing? I think the arm swing. Because as I said, maybe I just got used to it because of the many trials that I did. And the more I tried the more time I passed in exercising I would say the easier it was So yeah Yeah, it makes sense. How sure were you of your answers? If you got it correct in your home or not?

Definitely around 30% maximum. Right, right. Like, I'm very bad in figuring out my ways. So if I don't use Google Maps or any other support from friends or anybody else around me, no way. Is there anything else that you would like to share about the experience? I actually really enjoyed it and it made me realize even more that I need to work on my orientation. Because I feel like it's very important for the real world. But I would feel like your scenario could be turned into some kind of exercise for people like me to get along better with orientation. And I would actually try this. I would spend more time on this, but with more breaks because at some point I felt really exhausted. Yeah, yeah. That makes sense. Alright.

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p4 before:

Okay, have you used VR before? Yes, actually. How regularly? Not regularly, just once or twice for this course. So once or twice in total? Yeah. So roughly how many hours per week, or maybe before, not during exam week, have you played video games? What about your past?

I'm like 4.5 because I'm not that good at it but I'm not that bad at it either. We'll see. No, it's fine. Okay, do you have any dizziness or motion sickness issues? Do you get carsick? Actually, yeah, sometimes I get carsick but not always so I don't know. Have you experienced any dizziness with VR specifically? Maybe in your prototype last time, like you remember the broken one. I can't take from that as well. But otherwise, it's usually fine, yeah. Okay, perfect. Yeah, that's it.

p4 after:

So when you had to find your way home, how did you figure out where it was? What was your strategy? Honestly, like I couldn't really orient myself because it was just plain ground and there was no like

identifying lighting or anything. It was just more like subtle. So I literally just counted my steps and counted the turns. Yeah, that makes sense. Did you have any different strategies for arm swing and joystick? And no, I just counted the swings or counted the movement of the joystick. Yeah, also snap turns? Yeah, and snap turns. Okay. How did moving feel in each of the techniques, joystick and arm swing? It felt about the same, but I feel like the joystick, no, the arm swing, it made me feel like I

was moving forward a little bit more. I don't know, I'm used to this movement making me move forward, I guess. And then the visual feedback also. It just felt more physical. I felt like I could orient myself better for some reason. Right, right. And did you feel like you were actually traveling through the virtual space? Yeah, yeah. How easy or hard was each technique to use? So arm swing, joystick, head turn, step turn? Are you working as intended or are you just using the virtual space? I think I didn't use head turn at all. It's normal. Yeah, and joystick was very straightforward. Arm swing was pretty straightforward as well. And snap turn was easy as well It was just like the snap turn was just a bit unpredictable sometimes I feel Like because I don't know if you change the duration or the distance or whatever, but it felt like I couldn't predict where the snap turn would end up. Oh, okay. Yeah. I mean, it is consistent. Okay. Which technique do you think made it easier to find your way home? joystick or arm swing? Arm swing maybe, but not that different.

How sure were you of your answers? Very unsure. Probably like 50% confident.

Is there anything else that you would like to share about the experience? I don't know, can I ask you what exactly you're trying to test? I'm trying to see if like embodied cognition, if it's better to have something that resembles your normal movement Yeah, and how people find their way back Okay, but yeah, testing joystick versus an arm swing. What I would have felt

If there was some sort of Difference in texture I feel. That's kind of how I find my way around usually like or like some landmarks somewhere So I don't know if that would make it too easy, but I'm just thinking about it. Because it's very easy to disorient yourself when it's just a plain ground. Yeah, there's still texture in the grass, but it doesn't really help. It's the best thing. Alright, thank you!

G) Description of the code

TrialManager.cs

It runs the whole session from a single coroutine, RunSession(). For each technique it first calls Familiarization(), which gives the participant 30 s of free practice. It then calls RunBlock() twice. RunBlock() shuffles the four triangles with a Fisher-Yates shuffle, using a System.Random seeded by StableHash(participantId), so the same participant ID always gets the same order.

Each trial happens in RunTrial(). PlaceHeadAt() first rotates and moves the XR Origin so the participant's head stands on the start point, whatever their real position in the room. The pillars are then spawned one at a time, and WaitUntilReached() waits until the head is within 0.75 m of each one. For the return, WaitForConfirm() waits for the trigger (or the space bar, via ConfirmPressed()), and PlayConfirmFeedback() plays a short sound and a haptic pulse. While the participant moves, Update() samples the head position at 10 Hz to add up the outbound and return path lengths.

When the participant confirms, the errors are calculated from the head's floor position. Homing error is Vector3.Distance(finalPos, start), and angular error is Vector3.SignedAngle(trueHome, response, Vector3.up), measured from the second waypoint. Everything is stored in a TrialResult and sent out with TrialCompleted?.Invoke(result), so the logger can receive it without TrialManager knowing about the logger.

TrialLogger.cs

This script subscribes to TrialManager's TrialCompleted event in OnEnable(). In Start() it creates two CSV files with the same timestamp: one for trial results and one for head paths. Its own Update() buffers the head position, yaw and rig position at 20 Hz, capped at 12,000 samples. When a trial finishes, OnTrialCompleted() writes one row of results, and WritePath() keeps only the samples from that trial, labels each as out or return, writes them, and clears the buffer. All numbers use CultureInfo.InvariantCulture, so decimals are written the same way on any computer.

Data collection

Data is recorded in two places, at different rates. During each trial, TrialManager samples the head position in its own Update(). It adds up Time.deltaTime and takes a sample every sampleInterval = 0.1 s, so about 10 times per second. Recording starts in BeginRecording() at the start of the first leg and stops in StopRecording() when the participant confirms. Each sample stores the time since the trial started, the head position on the floor and whether the participant is in the outbound or return phase. The distances between samples are added up in lenOut and lenReturn, which give the path lengths and mean speed. These samples are only used for these calculations and are not saved to a file.

TrialLogger records the paths that are saved. It subscribes to TrialManager's TrialCompleted event in OnEnable() (trialManager.TrialCompleted += OnTrialCompleted;) and creates two CSV files with the same timestamp in Start(). Its Update() runs throughout the session and stores the head position, head yaw and XR Origin position whenever Time.time passes nextSampleTime, with sampleHz = 20. Samples are kept in a buffer that drops its oldest quarter once it passes 12,000 entries. When a trial ends, OnTrialCompleted() writes one row of results to the trials file, and WritePath() keeps only the samples since the trial began, labels each one out or return, writes them to the paths file and clears the buffer.

Both samplers run inside Update(), so they can only sample on a rendered frame. At 72 frames per second on the Quest, the 20 Hz logger therefore records about 18 samples per second. Both also track the head rather than the XR Origin alone, so leaning or turning the head adds slightly to the measured path length.

Mouse tracking inspiration for data collection

The path recording was inspired by mouse tracking, from my background in Cognitive Science, where a cursor's position is logged many times per second to study the whole movement rather than only the final click. Here, TrialLogger.Update() logs the head's x/z position on the floor at about 20 Hz instead of a cursor's x/y position on a screen. Each sample is labelled outbound or return, and the trigger press takes the place of the click. This made it possible to analyse full return paths (Figure 3), pauses and travel speed, not just where participants stopped.

H) README

Feeling Your Way Home: Arm-Swing vs. Joystick Locomotion for Path Integration in Seated VR

MGETXR Final Project, Clara Holst (s3980405), University of Twente.

A seated VR triangle-completion task. The participant travels two guided legs across a foggy, landmark-free grass field, then returns unguided to the start. The prototype compares two travel techniques: **joystick steering** and **arm-swing walking-in-place**. Both use the same speed and the same snap turning.

Assessed version

Commit 63f13876da2549437b48d14f3741aa70e9ddfa49 ("analysis")

Unity version

Unity **6000.3.23f1**

Demo scene

Assets/Scenes/Final_project.unity

Hardware and setup

- Meta Quest 1 (or a later Quest), connected to a Windows PC through Quest Link or Air Link, so the scene runs in Play mode in the Editor.
- The participant **sits** on a chair with room to swing both arms.
- **Log folder:** TrialLogger writes its CSV files to C:\Users\s3980405\MGETXR\mgetxr-final-csvs. To run on another machine, change the folder string in TrialLogger.Start() to a path that exists on that machine.
- Without a headset, the mechanic can be seen in the demo video: https://youtu.be/YU1eHaRrh0U

Running a session

1. Open the demo scene and select the **TrialManager** object. Set:

- Participant Id, for example P05. This also seeds the triangle order, so use a different ID for each participant.
- Joystick First: on for one half of participants, off for the other half, to counterbalance technique order.

2. Press **Play**. The session starts automatically (Start On Play).
3. The session runs as follows:
   - 30 s practice with the first technique.
   - 2 blocks of 4 triangles, with a break after each block.
   - The same again for the second technique.
4. In each trial:
   - The participant travels to the yellow pillar. When it disappears, the second pillar appears; they travel to that one too.
   - They then return to where they think the start was and press the trigger.
   - There is no accuracy feedback during the session.

Controls

Action	Input
Confirm / continue / mark home position	Right trigger (or **Space** on the keyboard)
Move (joystick condition)	Push the left thumbstick forward
Move (arm-swing condition)	Swing both controllers up and down in opposite directions
Snap turn 45° left/right	Right thumbstick left/right
Turn 180°	Pull the right thumbstick back
Look around	Head rotation

Both techniques move the player forward in the direction the head faces, at a fixed 1.5 m/s.

Output data

Each session writes two CSV files with a shared timestamp:

- trials_<timestamp>.csv: one row per trial. Includes triangle, homing error (m), signed angular error (°), trial time, return time, path lengths and mean speed.
- paths_<timestamp>.csv: head position and yaw at 20 Hz, labelled outbound (out) or return phase (return).

Dependencies

All packages are listed in Packages/manifest.json and install automatically when the project is opened:

- XR Interaction Toolkit 3.3.2, including the default Snap Turn preset. It brings in the Input System as a dependency.
- XR Plugin Management 4.6.1
- Oculus XR Plugin 4.5.4 and OpenXR 1.16.1
- Universal Render Pipeline 17.3.0
- ProBuilder 6.1.2
- uGUI 2.0.0, which includes TextMeshPro for the in-headset instructions
- No Asset Store assets.
- Hardware: Meta Quest headset with Quest Link or Air Link to a Windows PC.

Authorship

Declared AI path: **AI-assisted**.

Part	Origin
TrialManager.cs	Written with AI assistance (initial draft), then modified by me throughout
TrialLogger.cs	Written with AI assistance (initial draft), then modified by me throughout
JoystickLocomotion.cs	Written with AI assistance (initial draft), then modified by me throughout
ArmSwingLocomotion.cs	Written with AI assistance (initial draft), then modified by me. Swing threshold tuned to 0.4 m/s through pilot testing
XR Origin setup	Reused from my A6 assignment
Snap turning	XR Interaction Toolkit default snap-turn provider and preset (45°), reused from A6
Scene, environment and study design	My own

Known limitations

- TrialManager's Joystick Locomotion and Arm Swing Locomotion fields are left empty, so both techniques stay active in every block. This let each session run without restarting Unity. The researcher checked that participants used only the instructed input. To lock each block to one technique, drag both components from the XR Origin into those fields.
- In the study sessions, Participant Id and Joystick First were not changed. As a result, all participants used the joystick first and saw the same triangle order.