Moving On Up:
Investigating the Embodied Metaphor of Verticality and its Effect on Overconfidence

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.
I understand that my thesis may be made electronically available to the public.

Abstract

As investment in Virtual Reality (VR) continues, we sought to better understand the unique value proposition this technology has to offer by testing the impact of a virtually embodied metaphor on self-evaluation. In both experiments, participants completed multiple trivia rounds after experiencing different levels of verticality. We investigated whether the embodied metaphor of *UP = better* would then affect their overconfidence, measured as the difference between how well they estimated their own performance to be and how well they actually scored. In Experiment 1, we compared this effect between three different mediums: mental imagery, video, and VR, hypothesizing that the ascending VR condition would yield greater overconfidence scores. We speculated that VR, by engaging the body to a greater extent than the other two mediums, provides a mechanism through which the full effect of an embodied metaphor can activate. Our results did not support this hypothesis: we found no statistically significant difference in overconfidence scores between mediums in Experiment 1. However, Experiment 1 results did support our predictions that people perceive themselves to be more embodied in VR than they would be watching a video or imagining a scene. In a follow-up study with only mental imagery, Experiment 2, we found no main effect for contextual cues given during the experiment. There was a significant difference between ascending and descending conditions, however, *counter* to what we predicted: participants had higher overconfidence scores in the *descending* conditions. We discuss issues in the field of embodied metaphor research and suggest alternative routes for investigating metaphors in VR. In light of the growing interest in employing VR as a research tool, we discuss Experiment 1 methodologies, highlighting the advantages and disadvantages of conducting experimental research in VR.

Acknowledgements

This thesis is dedicated to my father, who surely would have had something insightful to add.

A deep thanks is owed to my supervisor, Dr. Colin Ellard, for his patience throughout this rollercoaster. I also offer my sincerest gratitude to my thesis readers, Dr. Mike Dixon and Dr. James Danckert, as well as to the larger Cognitive Neuroscience department for valuable feedback and ongoing inspiration. Comments, advice, and resources from past and present members of the Urban Realities Lab were indispensable and deeply appreciated: David Borkenhagen, Emily Grant, Dr. Robin Mazumder, Dr. Hanna Negami, and Jatheesh Srikantharajah. A special thank you goes out to my tireless research assistants, Kathyana Carvajal and Isha Shah.

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Introduction - Why VR?

Imagine slipping on your Virtual Reality (VR)[1] headset and finding yourself at the crest of a breathtaking mountain range. Not only are you instantaneously somewhere awesome, but there is also music playing and a fitness coach pumping you up. As you knock out the crescendo of your body workout routine, you turn your head and look around at the astounding view. You, like thousands of other daily Supernatural VR[2] users, have found yourself virtually and emotionally on top of the world. This is just one use case for VR, a technology that many prominent corporations and countries are betting on. Despite ongoing skepticism regarding the long-term consumer adoption of VR, companies like Meta continue to invest heavily in the technology; having spent $12 billion USD on its VR wing in 2021, Meta is expected to exceed that total spending by the end of 2022, despite infamous mass layoffs and a staggering 65% decline in share value (Manjoo, 2022; Rosenbaum, 2022). Abroad, the Chinese government recently published an action plan specifically devoted to VR, with the goal of having the Chinese tech sector ship more than 25 million units by 2026, a 48 billion dollar[3] endeavor (Ye, 2022). VR developers, entrepreneurs, and consumers are left wondering if the spending is worthwhile. Does VR really have a uniquely compelling value proposition that will endure beyond the appeal of its initial novelty? Why bother with VR when simpler, more affordable mediums like podcasts and video are already popular? In this introduction, we briefly summarize two existing avenues for evaluating the usefulness of VR (its capacity for

[1] Virtual Reality (VR) is a technology for seeing and interacting with a fully virtual world by donning a pair of goggles. These goggles are known as head-mounted displays (HMDs) and consist of a set of lenses and a high resolution screen (similar to a high end mobile phone screen). The visuals on this screen are then updated constantly based on the movements and inputs of the user, creating a sense of depth within an interactive environment, and, as a result, virtual experiences that are often indiscernible from real life. The essential purpose of VR is to transport the user somewhere else, whether to a mythical realm where warlocks can be defeated with deft spell casting, or to a carefully re-constructed factory floor for a training simulation.

[2] Supernatural VR is an immersive fitness application that takes place fully in VR.

[3] More precisely, 350 billion yuan or $48.20 billion USD.

simulating the real world and its ability to make content more immersive), and propose a third, unexplored lens: VR as a medium for invoking embodied metaphors.

Prior to the recent tech funding boom, VR developed slowly in select niches as an expensive but effective tool for a specific function: simulating real-world experiences that were otherwise highly difficult or impossible to facilitate. In military and corporate spheres, VR was and still is popular for flight simulation training (among other examples). Meanwhile in healthcare, VR has become a popular clinical tool for exposure therapy; there is a body of evidence to support the efficacy of VR-based exposure therapy programs to treat many psychiatric conditions, such as PTSD, body dysmorphic disorder, and a variety of specific phobias (Park et al., 2019). This is because VR experiences can, to some extent, elicit behavioural and physiological responses similar to real world experiences (Kisker et al., 2021), while allowing for a greater level of control for the professional facilitating the simulation. While these use-cases for VR are well validated and highly compelling, they serve niche audiences compared to technology with mass market adoption.

More recently (as the technology becomes more affordable), developers and researchers alike have explored a dimension of VR with potential for broader appeal: immersive content. Perhaps most prominently, there is a growing interest in understanding the potential role for VR in education (e.g., Hamilton et al., 2020; Wu et al., 2020) and everyday professional training (e.g., Howard & Gutworth, 2020; Kaplan et al., 2020). There is research indicating that using VR can lead to better learning outcomes than traditional mediums, particularly when lesson content has been appropriately matched with teaching method rather than arbitrarily utilizing VR for the sake of novelty alone (Huang, 2020). However, there is a need for more unified metrics when evaluating the efficacy of educational VR applications (Hamilton et al., 2020), and more broadly, the appeal of any immersive content in VR (such as video games, i.e., Sweetser et al., 2019).

One of the more pervasive metrics in VR research is presence, defined as the sense of *being there* that VR affords (Slater et al., 1995; Witmer & Singer, 1998; Riva et al., 2003). Though presence is a common metric in the literature on VR and important to investigate (e.g., Cummings & Bailenson, 2016), it has its shortcomings, in part

because VR is not the first technology to transport its users to another world. Research in media psychology has demonstrated that older media like literature and cinema have held similar claims (Klimmt & Vorderer, 2003), and even the prototypical format of oral storytelling around the fire can make an audience lose sense of the here and now. That sense of presence can depend on the quality of the story being told (i.e., Gorini et al., 2011), or more broadly, the emotional impact of the content (e.g., Riva et al. 2007). However, while the content is an important factor, we believe that there is something uniquely powerful in the way that VR facilitates *embodiment* within that content. In contrast to passively watching a film or imagining a scene, VR users truly sense themselves to be bodily present in the media itself. VR facilitates the sensorimotor experience of standing *in* the scene, with the ability to turn, look around, and - often - *take some sort of embodied action*, a nuance the metric of presence fails to capture (Carassa et al., 2004).

Because VR affords a unique capacity for users to experience embodiment, we looked towards the field of embodied cognition. Rather than comparing VR to real-world scenarios or measuring presence in VR compared to other mediums, we are interested in investigating that question while exploring a new avenue of research: VR as a platform for experiencing embodied metaphors. More specifically, how would an embodied metaphor in VR compare to exposure to metaphor in other, non-embodied forms of media (video and audio), and could such metaphors influence measures of cognition? The next section of this introduction will explore embodied cognition and embodied metaphors, and describe the specific research that influenced the experiments presented in this thesis.

Does Embodied Metaphor Theory Explain the Power of VR?

Embodied Cognition theory posits that our cognitive processes are influenced by our bodily experiences, such that the way we use our bodies, including interactions with our surroundings, affect the way we formulate ideas (Rosch et al., 1991). A relevant example of this comes from the field of linguistics: Conceptual Metaphor Theory describes how we understand an abstract domain in terms of another, more familiar, *physically-experienced* domain (Lakoff & Johnson, 2008). For example, in

framing career progression as *moving up the corporate hierarchy*, we apply the concrete experience of climbing a ladder to the more abstract concept of professional development. The multitude of metaphoric expressions and common idioms we use to express abstract ideas utilize all types of physical experiences and every axis of personal space as references. For example, we associate *up* with godliness and *down* with the devil (Meier et al. 2007), evident with phrases like, "Glory to God in the highest." We push meetings *ahead* and we fall *behind* schedule. We use *left* and *right* to discuss politics and we describe friends and family as *distant* or *close*. Metaphorical language that references physical experiences is ubiquitous.

When we engage in metaphorical thinking, we re-map our embodied experience to an abstract concept, but research has demonstrated that the inverse can also be true: when we embody a particular physicality, we also invoke the concepts associated with it. A large body of empirical work indicates that, at the very least, we can be certain that some portion of the neural mechanisms involved with observing or imagining a task, overlaps with the mechanisms used for actually doing said task (Rizzolatti et al., 1996; Avanzini et al., 2012). What is unclear, however, is the extent to which we activate abstract concepts through physical experience and action. Embodied metaphor researchers have investigated a variety of interesting instances: for example, people asked to *literally* think outside of a physical box demonstrated more creative thinking (Leung et al., 2012), and participants asked to generate positive thoughts found it easier to do so when sitting upright as opposed to slouching (Wilson & Peper, 2004). Some enacted embodied metaphor effects have failed to replicate, however. For example, Lynott et al. (2014) were unable to reproduce the results of Williams and Bargh's 2008 study on social warmth, and Earp et al. (2014) failed to replicate Zhong and Liljenquist's 2006 results that physically washing one's hands can relieve threatened morality. There is an ongoing debate around these inconsistencies: some researchers cite researcher bias (e.g., Lynott et al., 2012), while others think the theoretical framework itself is insufficient and cannot adequately predict experimental outcomes (Lakens, 2014; Kompa, 2017). While we cannot resolve the broader debate within the scope of our work, issues in the field have highlighted

both a need to exercise caution in interpreting results and an ongoing need for replication studies.

Ultimately, we are particularly interested in research on embodied metaphors, as this could have interesting implications for both understanding VR and potentially unlocking useful applications in therapy and self-help. It is common for mental health specialists to leverage metaphors during treatment, whether in investigating a patient's issues, or in helping them uncover new perspectives (Martin et al., 1992; Tay, 2013). Metaphor is also an important aspect of preventative self-help based mental health practices like meditation, where individuals practice *grounding* themselves (e.g., Silvestre-López et al., 2021). Future research could build on our investigation to determine if the utility of metaphor could be amplified with VR in these various contexts. Despite the replication controversy in the field of embodied metaphor research, we found these applied metaphor-use cases compelling enough to investigate one particular embodied metaphor effect in conjunction with VR: verticality.

Verticality as an Embodied Metaphor: The Present Studies

Let us return to the aforementioned VR mountaintop scenario, and ask ourselves: how did it feel to be at the top? In physical terms, users were uplifted on the top of a mountain. To be "uplifted" is also a metaphorical expression associated with confidence and aspiration. We describe socioeconomic progress as *upwards* mobility, and we call a promising athlete a *rising* star. We *climb* the ranks and we *boost* our confidence. The cognitive and emotional effects of verticality have been of interest to researchers for decades, perhaps the earliest example being Wilson's 1968 finding that taller people are perceived to be more powerful than shorter people (when judgements about power are made in absence of other information about status). More recently, verticality has been submitted to empirical research under the theoretical paradigm of embodied metaphor research.

Our research was specifically concerned with vertical space, because there are a number of studies looking at how verticality affects perception and judgment (for a

review, see Cian, 2017). Three studies in particular form the foundation for our research. In the first study, Slepian, Masicampo, & Ambad (2015) approached students on a university campus, seemingly at random, and asked them to fill out a survey. Some students had just *ascended* a set of stairs when they were approached, while others had just *descended* a set of stairs. It was found that ascending a flight of stairs was associated with higher order thinking (discussing more abstract goals spanning farther into the future) compared to the group that had just descended the stairs. Later, just showing students photos from the same vantage points produced similar results.

In a different study, Sun and colleagues (2011), asked participants to stand at a window and contemplate the view (ostensibly, to clear their minds) before completing a general knowledge quiz. Participants were then asked to guess how well they had scored on the quiz, with the difference between their estimated and actual score serving as a measure of overconfidence. In Sun et al.'s first experiment, one group of students contemplated the view from a classroom on the second floor of a building, while the other group had an eighth-floor vantage point. Sun et al. found that study participants in the *higher-up* condition overestimated their quiz scores more than students in the *lower-down* group. In a follow-up experiment, participants were shown photos of a view—either from the second or eighth floor (rather than seeing the view first hand). Again, students who viewed the eighth-floor views had higher overconfidence scores.

Lastly, Ostinelli, Luna, and Ringberg (2014), found that when participants were asked to imagine going up in an elevator or taking off in an airplane, they reported higher self-worth. The researchers found that just *thinking* about a physical experience of verticality was enough to affect participant attitudes and behaviours.

All three studies discussed above (Slepian, Sun and Ostinelli) investigated verticality, but there were important differences in their methods. In the Slepian et al. study, participants *physically* ascended/descended stairs in some experiments, but only looked at photos in other experiments. Similarly, in the Sun study, the researchers had students *physically* situated on the 2nd or 8th floors of a building, but also had a follow-up study wherein students only looked at *photos* of those views. In

contrast, the participants in Ostinelli's 2014 study engaged only with mental visualizations. No study (to our knowledge) has compared all three levels of embodiment in the same experiment.

In our experiments, we sought to replicate and extend this existing Conceptual Metaphor Theory research. Firstly, we wanted to replicate Sun et al.'s 2011 verticality effect in VR. Our aim was to confirm that embodying a metaphor calls upon the ideas associated with it, creating an embodied metaphor effect. Our second goal was to extend previous research by investigating the interaction effect of embodiment on the relationship between verticality and self-confidence. We asked: does greater embodiment in VR thereby correlate with a larger embodied metaphor effect (compared to mental or visual-only exposure to the same metaphor)? We manipulated verticality (neutral vs. higher-up in Experiment 1 and ascending vs. descending in Experiment 2) to investigate its effect on overconfidence.

Overconfidence

Following the 2011 Sun et al. study, both of the experiments discussed in this thesis examine the effect of verticality on overconfidence. For the purposes of this thesis, overconfidence is defined as the difference between someone's estimate of their own performance on a task (in this case, a trivia test) and how well they actually performed (see Moore & Healy, 2008 for a discussion on other definitions)[4]. Logistically, overconfidence was an appropriate choice because it could be measured remotely online / in VR without any special equipment (such as an ECG). This was important given COVID-lockdown restrictions on in-person experimentation. Furthermore, overconfidence can be measured a the state level as a response to particular stimuli, as opposed to trait measures like self-esteem and self-efficacy.

[4] Moore and Healy (2008) describe three primary definitions for overconfidence within empirical research: overestimation (overestimating your performance), overplacement (an inflated sense of being superior to others), and overprecision (excessive confidence in the credibility of your beliefs). When we discuss overconfidence, we are referring to what Moore and Healy discuss as overestimation, the most common definition.

On a broader note, overconfidence was an attractive metric to us because we are interested in areas of cognition that have possible bearings on mental health outcomes. A moderate amount of overconfidence has been associated with a range of positive outcomes related to well-being, psychological adjustment, and social success (e.g., Taylor & Brown, 1988; Taylor & Lerner, 2003; Dufner et al., 2012; Murphy et al., 2018). In contrast, there are broad assertions that overconfidence is to blame for a variety of serious issues, from gambling addictions (Goodie, 2005) to global catastrophes (Plous, 1993). Despite these downsides, overconfident populations still prosper, indicating that the advantages can outweigh the disadvantages (Johnson & Fowler, 2011). As is the case for many psychological traits, overconfidence is likely a Goldilocks quality: too little is detrimental, an excess is problematic, and a "right amount" is ideal

Having discussed the overall backdrop of this thesis, it is important to emphasize that our experiments on verticality also provide the opportunity to compare embodied effects between mental imagery, video, and VR. An overarching interest of this thesis is to understand if content displayed in VR yields a greater effect size on measures of cognition compared to other media. If a spatial metaphor experienced in VR influences cognition more so than if displayed on a video or described in an audio clip, then VR can be considered to possess a unique affective ability. Therein may lie the unique value proposition of VR. In the next chapter, I will discuss Experiment 1 (Virtual Escalators). Based on unintended results from Experiment 1, we conducted Experiment 2 (Imaginary Staircases) as a follow-up study, which I will discuss in Chapter 2. A summary of both experiments and their limitations can be found in the last chapter, along with suggestions for future research.

Experiment 1 - Virtual Escalators

1.1 Introduction

Experiment 1 employed a within-subjects 2 x 3 design (Figure 1). Our objectives were two-fold. First, we sought to partially replicate[5] previous research indicating that higher verticality increases overconfidence by manipulating verticality by moving a group of participants up an escalator and comparing their overconfidence scores to a group of participants that moved across a flat plane of the same distance. Second, we sought to compare VR to less embodied mediums, asking whether level of embodiment (mental imagery, video observation, or embodied movement) interacts with participants' overconfidence scores.

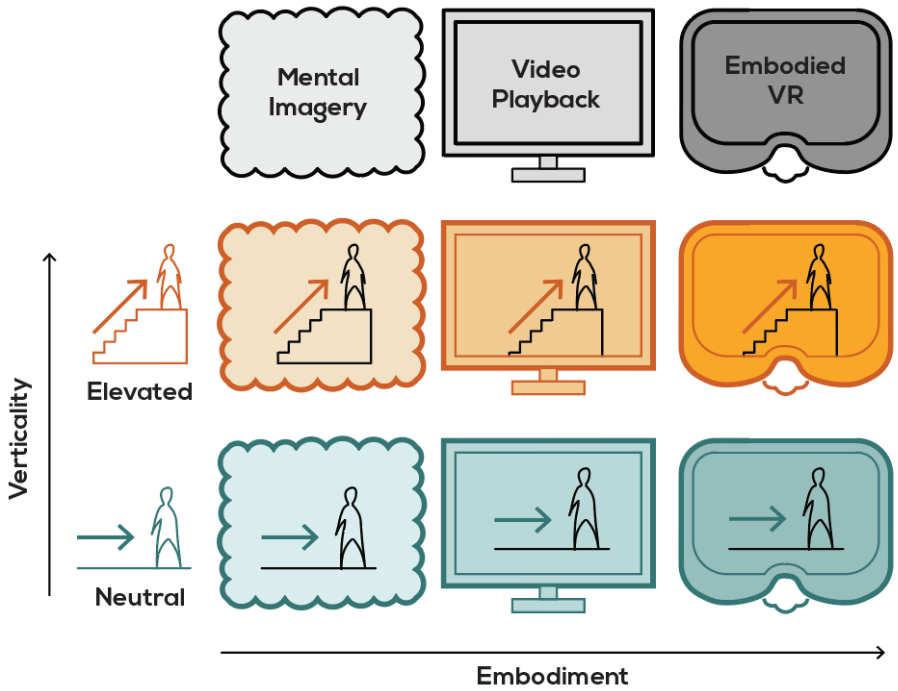

Figure 1. Graphical depiction of the two axes we investigated in Study 1: verticality (with two levels, moving across a space or upwards through it) and embodiment (with three levels: mental imagery, video, or movement in VR).

[5] In Experiment 1, we followed aspects of Sun et al. (2011). Because we were also examining a verticality effect across mediums (a dimension not explored by Sun et al. 2011), we avoided overcomplicating our study by excluding certain measures investigated by Sun et al., namely peer comparison, processing style, and scale direction.

Because of pandemic-related restrictions, we administered this study using a novel system: remote Virtual Reality (VR). We recruited participants from the user base of an existing VR platform: AltspaceVR. This is a social VR platform, meaning that it is an application designed for users to embody avatars (digital bodies) and gather in virtual environments. AltSpaceVR is free, with a user community of thousands of people who already own VR headsets. This provided us with an interesting opportunity to conduct virtual "in-person" VR-based embodiment studies at a time when bringing participants into a physical lab was not possible. For more information on AltspaceVR, see Appendix A.

***Figure* 2.** Technical setup of a remote virtual experiment appointment.
Left: A participant (physically located anywhere in the world) would don a virtual reality headset and experience the experiment as an embodied avatar. The participant would see the researcher as an avatar present in the environment with them.
Right: The research team would administer the experiment via a desktop connection, using Qualtrics on a separate monitor window to randomize the experiment flow and collect participant responses.

There were a couple of other advantages to using AltspaceVR as a platform for both recruitment and experimentation. First, participants were already familiar with the experience of VR itself, reducing the likelihood of the awe effect. This is an issue for many VR-based studies, wherein participants are so excited by the novel experience of being in VR for the first time that it affects their task performance and survey responses. Second, experienced users of the platform already have an understanding of the risk of motion sickness commonly associated with VR. Though

there were a couple of exceptions, most users that were already comfortable in a typical AltspaceVR environment had no issues participating in our study. We anticipated that recruiting from a population of AltspaceVR users would reduce the chances of participants experiencing simulator sickness.

1.2 Method

Participants

Choosing a Cohen's f of .1, we conducted a power analysis of three conditions, and multiplied the results by 2 to reflect the 2x3 design. This calculation produced a target sample size of 300. Our final sample size, however, was much smaller: 74[6] (Figure 3). We actively recruited participants for four months, through online posting on Twitter, Discord, and Instagram, and through several virtual recruitment events held virtually in AltspaceVR itself. Participant sign-up rates were fairly steady for three months, but eventually tapered out later in the five-month study period. We closed the study one month after sign-ups stopped. For more details on recruitment and study attrition rates, see Appendix A.

Procedure

After filling in a demographics questionnaire, participants signed up for individual appointments with a member of the research team. At the designated appointment time, a member of the research team would teleport a subject to the private experiment world, and lead them through different rooms in the virtual environment (Figure 4).

[6] Note that the Sun et al. study we were replicating had 98 participants in Experiment 1, 101 participants in Experiment 2, and 97 participants in Experiment 3. Our sample size needed to be larger, however, because of the cross-medium comparison.

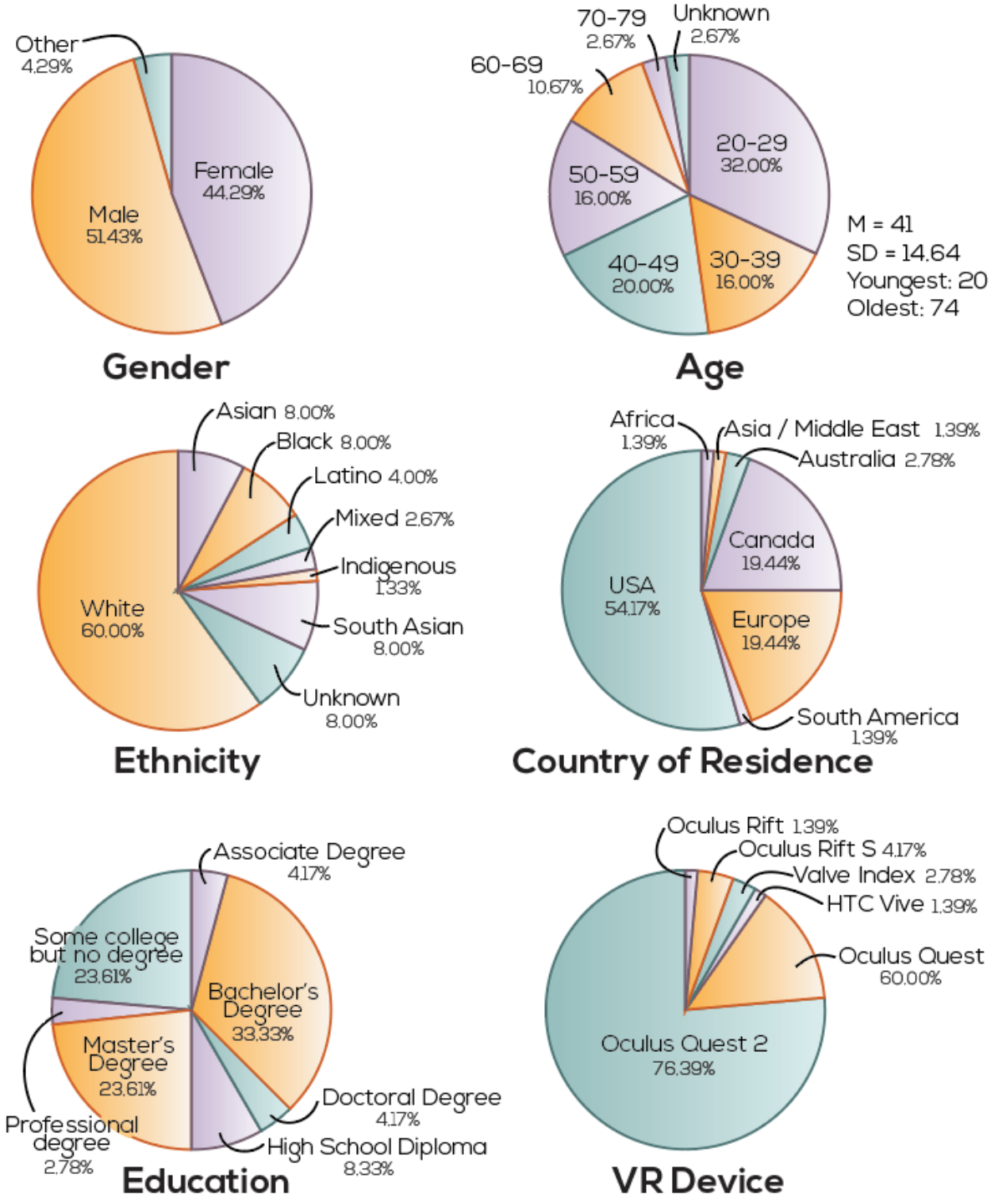

Figure 3. Pie charts depicting Experiment 1 demographics (N = 74). Though not truly culturally diverse (especially given that the experiment was only offered in English and that Altspace is primarily favoured by North American VR users), the study benefited from a more diverse sample than most experiments run with university undergraduate participants.

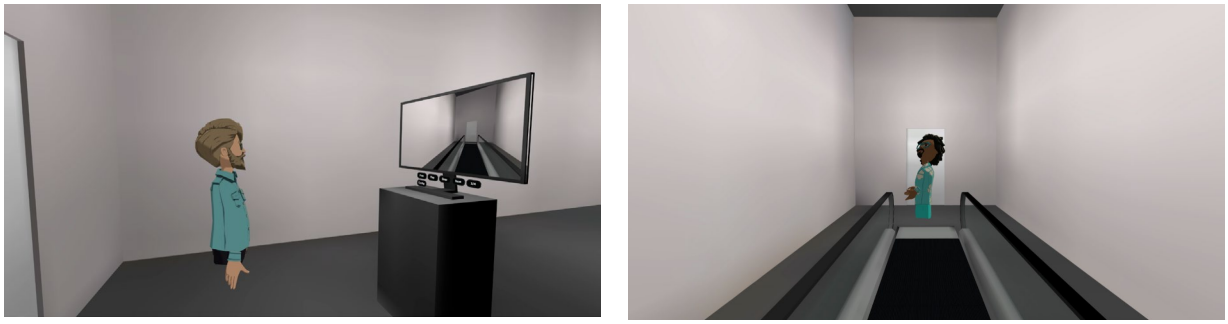

Figure 4. Screenshots of participants going through the experiment in AltspaceVR. The experiment took approximately one hour to complete.
Left: A participant viewing the video playback condition.
Right: A participant moving through the neutral verticality virtual embodiment condition.

Participants experienced six different conditions three times each, such that there were 18 trials in total (Figure 5). The order in which participants moved through the different conditions was block-randomized to control for order effects.

1. *Experiencing higher verticality with mental imagery*: Participants were prompted by an audio recording to imagine ascending an escalator.
2. *Experiencing neutral verticality with mental imagery*: Participants were prompted by an audio recording to imagine moving across a room on a moving walkway.
3. *Experiencing higher verticality by watching a video*: Participants watched a video of ascending an escalator.
4. *Experiencing neutral verticality by watching a video*: Participants watched a video of moving across a room on a moving walkway.
5. *Experiencing higher verticality in virtual reality*: Participants embodied an avatar ascending an escalator.
6. *Experiencing neutral verticality in virtual reality*: Participants embodied an avatar moving across a room on a moving walkway.

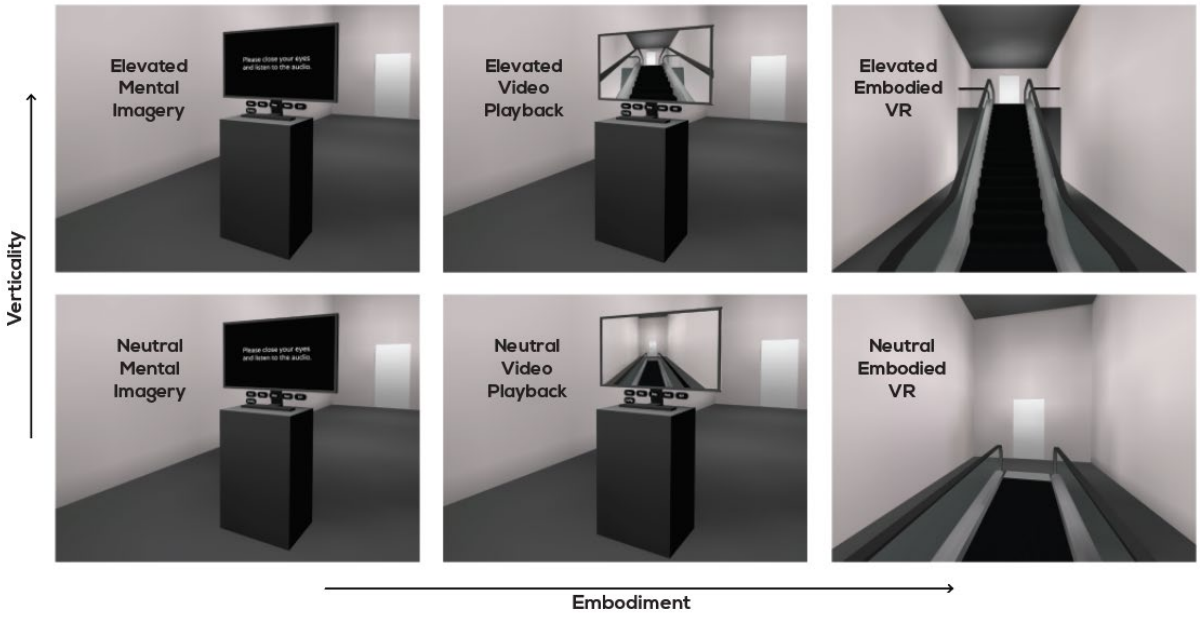

Figure 5. Screenshots of the six conditions in the experiment overlaid with a graphical representation of the two factors of study.

Participants were not told what the true hypothesis of the experiment was until after they completed all the trials. Instead, we told participants that we were interested in how moving through a space, both horizontally and vertically, can affect someone's perception of its volume, and that we were comparing that effect across mediums. To facilitate this deception, the researcher would ask the participant after every round of the experiment: "Please estimate the length, width, and height of the room you just [imagined / experienced / viewed]. In whatever units you feel comfortable with." Though every room was, in fact, the same size, the researcher did not point this out or otherwise comment on it.

After each of the 18 trials, participants completed three tasks:

1. *Mock spatial perception task*
2. *Rapid fire trivia*: participants were verbally asked ten trivia questions spanning a range of topics, including music, geography, world history, sports, movies, and science (Appendix B)
3. *Trivia performance estimate*

Measures

Demographic Questionnaire. Prior to the experiment, participants completed a questionnaire that included optional demographic information.

Immersive Tendencies Questionnaire (ITQ) (Witmer & Singer, 1996). The pre-experiment questionnaire that participants completed included ITQ. Eighteen questions long, the ITQ scores participants' propensity for becoming immersed in media (Appendix C).

Overconfidence. Consistent with work by Sun et al. (2011), the dependent variable in this experiment was the overconfidence score after each of the 18 trials: the difference between the participant's estimated score and their actual score on the trivia round. To facilitate the deception, we told participants that these trivia rounds and overconfidence questions were meant to be a mental resetting exercise to distract them between conditions.

The highest possible overconfidence score would be 10 (participant estimated perfect accuracy but scored zero), and the lowest possible overconfidence score would be -10 (if participant estimated 0/10 but somehow scored a perfect 10/10).

Manipulation Checks. At the end of the experiment, the researchers verbally asked a series of manipulation check questions to assess how embodied participants felt in each condition, and how great a sense of presence they felt. Participants were shown an image to remind them of the response options (not at all / a little bit / moderately / severely). For the full list of questions, refer to Appendix D.

Simulator Sickness Checks (adapted from Kennedy et al., 1993). Also, during the post-experiment debriefing, the researchers assessed any potential simulator sickness[7]. The following prompt was verbally stated: "I will list a series of symptoms. For each symptom, please verbally answer how much that symptom affected your performance on the tasks during the experiment." For the list of symptoms, refer to Appendix D.

[7] Please note that the researchers would also check in with participants throughout the experiment to ensure they were feeling well enough to continue. Any participants who felt sick in any way before completing all the trials were encouraged to take a break or stop altogether. These participants were still remunerated, but their data was removed from the analysis.

Deception Checks. At the end of the appointment, participants were asked if they had any suspicions about the study or guesses about its true purpose. They were then debriefed on the real purpose of the study. For the full script, refer to Appendix D.

1.3 Results

Two participants who were not able to finish the experiment (due to motion sickness or otherwise) were removed prior to analysis. We did not remove any participants based on their responses to manipulation or suspicion checks.

Overconfidence

Though our dependent variable, overconfidence, typically refers to participants *over*estimating their own performance, our participants usually *under*estimated their performance ($M = -1.33$, $SD = 1.14$). To mitigate order effects, we analyzed the mean overconfidence scores of repeated trials (such that we analyzed one mean score for both ascending mental imagery trials, both neutral mental imagery trials, and so on). Mean overconfidence scores for each condition are illustrated in Figure 6.

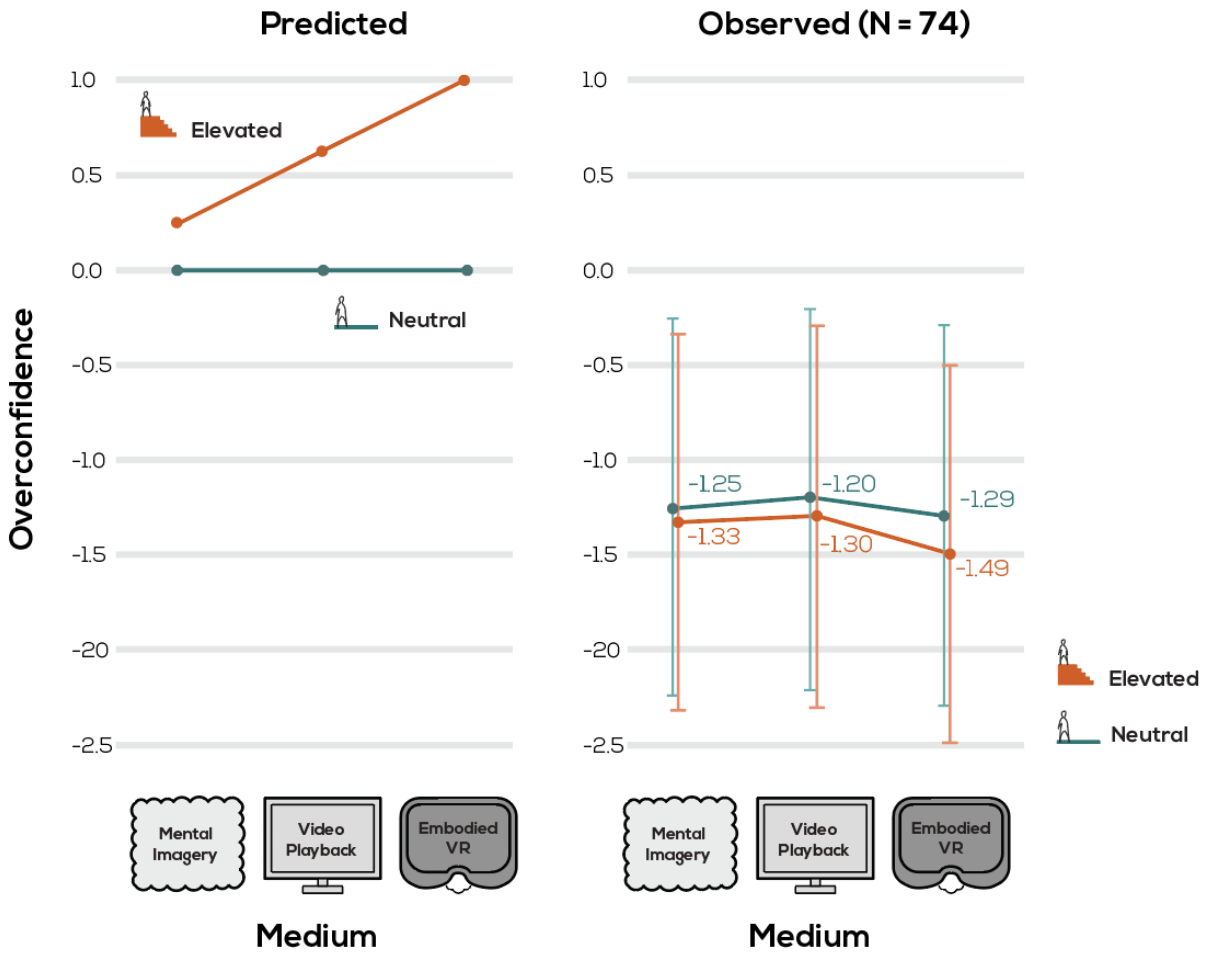

Figure 6. Graph depicting the hypothesized vs observed mean overconfidence scores for Experiment 1 (error bars indicate the standard of deviation).

Overconfidence scores were normally distributed ($p > .05$) except for the elevated video condition ($p = .001$), as assessed by Shapiro-Wilk's test of normality on the studentized residuals greater than ± 3 standard deviations. This exception was due to one outlier that we chose to retain. A 2 x 3 repeated measures ANOVA was conducted to compare estimates of trivia scores after experiencing these six conditions. We hypothesized that participants would have higher overconfidence scores when they imagined, viewed, or experienced upwards movement, and lower overconfidence scores when they imagined, viewed, or experienced a forward movement on a level plane (a moving walkway). We also predicted a main effect for elevation: that overall, overconfidence would be greater in the elevated conditions compared to the neutral

conditions. There was no statistically significant two-way interaction between verticality and medium, $F(2, 146) = 0.158$, $p = .854$, partial $\eta^2 = .002$ (N = 74). As such, this experiment failed to provide evidence for verticality affecting overconfidence, and furthermore failed to provide evidence that medium affects the degree to which verticality might affect overconfidence. We cannot reject the null hypothesis and cannot accept the alternative hypothesis.

Reported Embodiment

We also analyzed reported embodiment (using manipulation check scores, see Appendix D), predicting that scores would be highest for the VR condition (Figure 6). Because reported embodiment scores were not normally distributed (as assessed by inspection of a boxplot), we ran a Friedman test to compare reported embodiment between mental imagery, video, and VR. Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons. Reported embodiment was significantly different in response to different mediums, $\chi^2(2) = 86.812$, $p < .0005$ (N = 74). Reported embodiment was greater for the VR condition compared to video ($p < .0005$) and mental imagery ($p < .0005$). The predictions that participants would report feeling more embodied in the VR condition was supported. We found that the second-highest reported embodiment mean was associated with Mental Imagery condition, not the Video Playback condition as we expected (though this difference was not statistically significant).

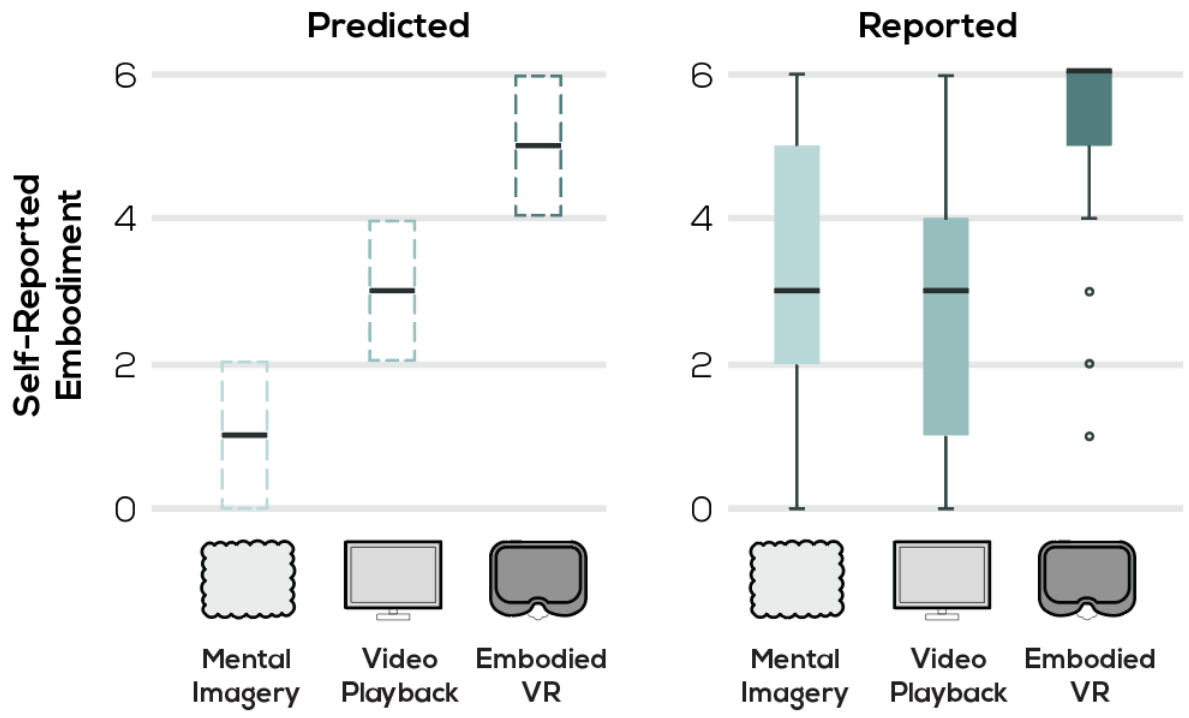

Figure 7. Box and whisker plots (boxplots) of predicted vs reported embodiment scores.

1.4 Discussion

Contrary to our hypothesis that overconfidence would be greater in the higher verticality conditions (and greatest in the more embodied VR higher verticality condition), we found no evidence for such a verticality effect during Experiment 1, nor could we reject the null hypothesis. The results of Experiment 1 consequently did not replicate the findings of Sun et al. (2011).

Our unanticipated results might indicate that some other factor is necessary to produce a verticality effect, such as a greater sense of prospect. Future studies could utilize a more exaggerated height difference (sending participants multiple storeys upwards instead of just one storey) or even include windows with an expansive view in the heightened verticality condition. Our intention in designing this study was to distill a verticality effect, removing as many complicating factors as possible. However, our results may indicate that a *set* of environmental features (or concepts) might be required to activate an embodied metaphor.

It is also possible that unavoidable complications in our study methods influenced our results. One of the unfortunate consequences of using AltspaceVR was that participants noticed a slight jittering in their field of view when moving through the embodied versions of the moving walkway and escalator. In order to explain why this happened, it is necessary to describe some additional details about the experiment methodology and the challenges and opportunities of running a study in VR. Generally, AltspaceVR users move through virtual space by pressing a button to "teleport" or by holding down a joystick to move continuously. In contrast, real life movement usually involves physically engaging one's motor system, i.e., *walking*. Incongruencies like this can lead to nausea and diminish a sense of virtual embodiment (the sense that the avatar you are controlling is an extension of your actual body), possibly negating any embodied metaphor effects. "Teleporting" with a button can mitigate such a reality contradiction to some degree (rather than a mismatch, it feels like magic), but we could not study the effects of moving through space with teleportation, given that it skips the act of moving altogether. Had we run a real-world version of this experiment, asking participants to climb a staircase, they would have engaged their legs and core to ascend a set of stairs. This is, fundamentally, a different sensorimotor experience than standing in place while pressing a joystick to ascend a set of *virtual* stairs. Standing in place while ascending an escalator, however, is more akin to standing in place while ascending a virtual escalator (at least, comparatively). As such, we designed the experiment to include escalators and moving walkways rather than staircases and flat floors so that a participant's sensorimotor experience matched with their visual feedback (and a real world, familiar experience) as closely as possible.

In order to mimic a real life escalator / moving walkway, we designed virtual mechanisms[8] to push the participants along. This had the added benefit of ensuring participants moved through the conditions at a consistent speed. However, because such virtual mechanisms are not officially supported by AltspaceVR, the platform did not handle this movement as smoothly as we would have desired, leading to a jittering

[8] Technically speaking, animated "rigidbodies" imported from a software called Unity.

effect in participants' vision. Though the jittering effect was minimal, and most participants did not comment on it, some participants reported that this disrupted their sense of immersion and / or made them feel slightly nauseous. Based on this feedback, it would have been better to design the experiment without these pushing mechanisms, allowing users to move with their own AltspaceVR joysticks instead. Alternatively, it might have been worth exploring an experiment design based not on *moving through* space (as in Slepian et al.'s 2015 study where students ascended/descended stairs), but performing a short task from certain vantage points (as in the original Sun, Wang, & Li's 2011 views-based experiment design).

While the technical nuances of conducting Experiment 1 in Altspace VR were challenging, it is also worth highlighting the advantages. As with in-person lab experiments, participants were engaged in the procedure such that we did not need to eliminate any subjects due to inattention (as is typical with online studies). Second, the resulting demographics (as illustrated in Figure 3), while not accurately representative of the overall population, were at least much more diverse than a typical sample of undergraduates. However, it is worth noting that it is difficult (if not impossible) to make a general knowledge trivia test appropriate for a globally diverse sample. Participants hailing from countries outside of North-America and the UK complained that they were unfamiliar with pop culture themes referenced in the trivia questions. Similarly, western participants had qualms about international geography questions.

Overall, a major limitation of Experiment 1 was that participants did not generally *enjoy* the trivia, and, consequently, the experiment as a whole. Though this is not uncommon for experimental research (which often involves repeating tedious tasks for long periods of time), the great number of trivia questions in this study contributed to participants experiencing mental fatigue. The vast majority of the participants perceived themselves to be "bad at trivia," and were especially alarmed by trivia categories that were unfamiliar to them. By design, we formulated trivia question sets to include easy questions, medium-difficulty questions, and difficult questions. We *intended* for participants to be asked questions from unfamiliar categories (perfect trivia performance would have yielded useless overconfidence

results), and yet we did not anticipate the level of distress participants would experience from performing poorly (in their minds) on the trivia rounds. As previously mentioned, participants were *under*confident in most cases. As such, this study became an investigation of what medium / verticality conditions might foster *less* underconfidence.

In a similar vein, moving walkways may have been an inadequate control condition. It is possible that *moving forward* could be associated with *increased progress* (and thereby, overconfidence) as much as *moving upwards* is. As such, we explored an alternative control in Experiment 2.

Experiment 2 - Imaginary Staircases

2.1 Introduction

In Experiment 1, we failed to find evidence for a verticality effect on overconfidence. A possible shortcoming of Experiment 1 was its control condition: a moving walkway. *Moving forward* has its own metaphorical associations with *forward progress*, such that it might not be a true control compared to *moving upwards*. In Experiment 2 we sought to address that issue, using *moving downwards* as a control instead. Experiment 2 was conducted as a 2 x 2 mixed between-group and within-subject study design (Figure 8). Rather than comparing across different mediums, Experiment 2 focused on one medium – imagery – and refined the protocol in an attempt to uncover the verticality effect. Again, we sought to partially replicate previous findings that verticality affects overconfidence, focusing on one medium.

There is existing literature in the field of embodied metaphors indicating that mental imagery can produce an effect on self-evaluation (for example, the Ostinelli et al., 2014 study discussed in the Introduction). In Experiment 2, we focused our resources on examining the relationship between *imagined* verticality and overconfidence. We asked participants to imagine a staircase that they either ascended or descended (rather than utilizing a complex animated virtual escalator / walkway, as in Experiment 1), predicting that the ascending conditions would yield higher overconfidence scores.

We also explored a new question in Experiment 2: how does context affect an embodied metaphor effect? More specifically, how do *congruent vs incongruent contextual statements* affect the relationship between verticality and confidence? In the Context Group, mental imagery prompts included statements relating to capability: "*As you ascend / descend, imagine yourself becoming more and more capable with every step*," (whereas the No Context Group had no such cues). Our hypothesis was that overconfidence would be highest in the ascending congruent context condition and lowest in the descending incongruent context condition.

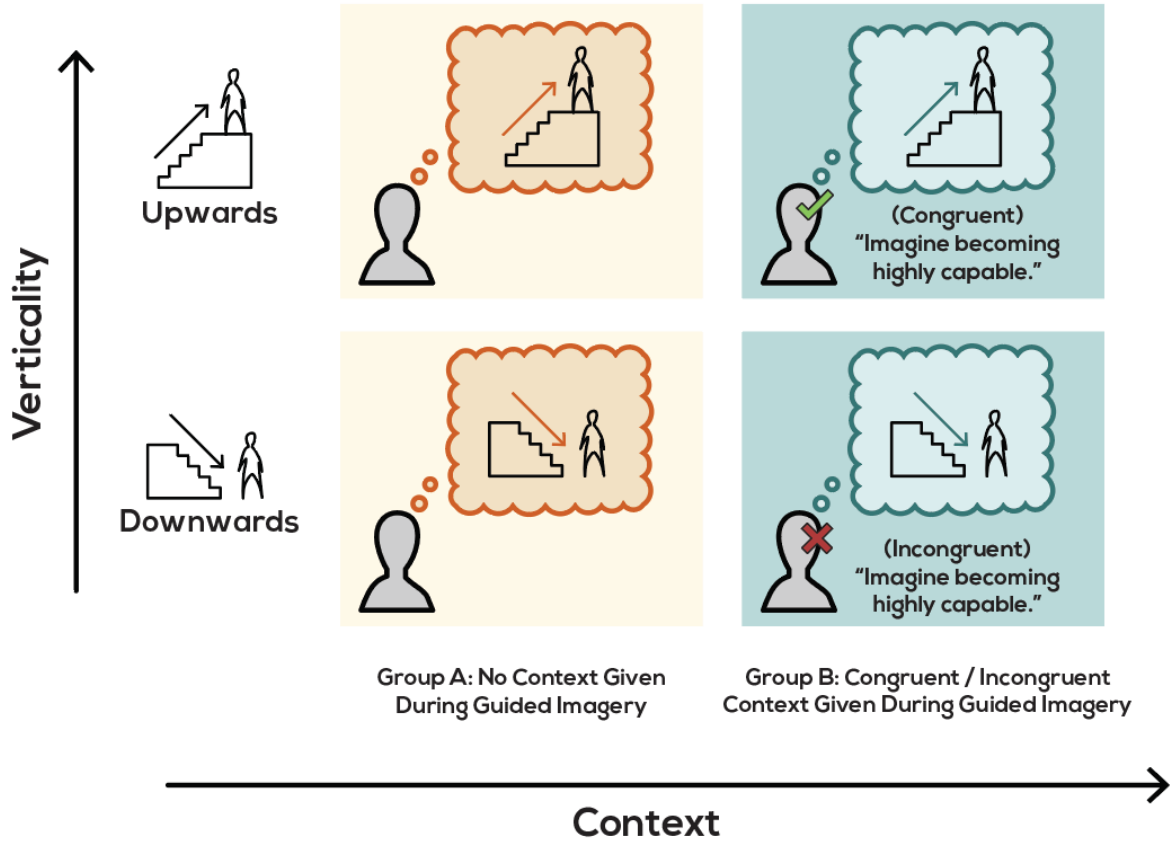

Figure 8. Diagram depicting the two axes of study in Experiment 2: Verticality and Context. There were two groups within the study (Group A: No context given during guided imagery and Group B: Congruent / incongruent context given during guided imagery) and two conditions across both groups (imagining ascending the stairs and imagining descending the stairs). We predicted that the differences in overconfidence scores between ascending and descending conditions would be greater in Group B than in Group A.

2.2 Method

Participants

Following similarly structured studies looking at mental imagery with undergraduate students (ie. Ostinelli et al, 2014; Wood et. al, 2009; Karimpur & Hamburger, 2018) our target sample size was 80. A total of 77[9] University of Waterloo

[9] It was decided a priori that participants would be collected over the course of the Spring 2022 term. Specifying the recruitment goal of 80 in our study listing on SONA (a tool for researchers to connect with undergraduate students), we fell just shy of our target by the end of the term.

undergraduate students participated in this study for course credit. Prior to analysis, we eliminated 11 responses for being incomplete or failing to pass attention checks, one response for reported technical difficulties, and one response for withdrawing consent following experiment debriefing. As such, our final sample size was 64 (43 women, 20 men, 1 agender; M age = 21.05, SD = 3.58).

Procedure

Experiment 2 was administered online through Qualtrics. Participants, who participated on their own time, were told to go through the experiment in a quiet place in order to listen to the audio prompts without disruptions. The experiment itself took 30 min on average to complete.

Participants were randomly sorted into two groups: A for no context (n = 30), and B for context (n = 34)[10]. All participants would imagine ascending and descending the same set of stairs (Figure 9), but the two groups differed in whether or not they receive context for the accompanying ascending / descending imagery prompts (for full scripts, see Appendix E):

(A) Group A ***had no context*** for the mental imagery prompt:

"Imagine yourself **ascending** a set of stairs."

"Imagine yourself **descending** a set of stairs."

(B) Group B ***did have context*** for the mental imagery prompt:

Congruent: "Imagine yourself **ascending** a set of stairs. *As you ascend, imagine yourself becoming more and more capable with every step*."

Incongruent: "Imagine yourself **descending** a set of stairs. *As you descend, imagine yourself becoming more and more capable with every step*."

[10] Out of 77 participants, we only received and analyzed 64 valid responses. Though the survey was set up to evenly distribute participants between the two between-group conditions, the valid responses happened to be disbalanced. As such, response counts in group A and Group B are unequal.

Figure 9. The image of a staircase (created by the author) shown to all participants across conditions as part of every trial. Participants were told to close their eyes and imagine ascending / descending these stairs during the accompanying guided imagery audio prompt.

Every participant went through four trials in total (experiencing the ascending and descending conditions twice). Before the mental imagery prompt, every trial would begin with a round of a general-knowledge trivia quiz. In Experiment 1, we found that participants were generally overwhelmed by the large number of trivia questions (120 in total) and the feeling of being "bad at trivia" (verbally reported by many participants, even those with higher-than-average scores). Though some of these issues are inherent to using overconfidence as a measure, we attempted to improve upon our method in Experiment 2 by:

- Reducing the overall length of the experiment and the number of trivia questions given to each participant (from 120 to 80). We looked at overall performance on different trivia questions by demographic, specifically analyzing answers from participants in the 20-25 year old age range. We

ranked the questions into different difficulty categories (easy, medium, difficult) depending on how many people in that 20-25 age range correctly answered them, to create balanced trivia sets. Each set included 11 easy questions, six medium-difficulty questions, and three challenging questions.

- Increasing the number of questions in a particular trivia round from 10 to 20, which gave more fidelity to our primary measure of interest (overconfidence). We hoped that this would have the added benefit of giving participants the impression that their performance was acceptable and not a cause for anxiety ("10 out of 20" might feel better than "5 out of 10").

To facilitate a deception, we included an additional cover task at the end of each trial. As with Experiment 1, participants were unaware of the true purpose of the experiment until after they completed all the trials. Subjects were told that the study aim was to investigate how depth perception was influenced by different guided audio prompts. After every trial, we showed participants a random view of the same room (Figure 10) and asked them: "Please estimate the length, width, and height of the room shown in the photograph above. Use whatever units you feel comfortable with (meters or feet)."

Figure 10. Images of the same room from different angles (created by the author); a door was included in the design to give a sense of scale. Every participant was shown each of these four images in a random order. The researchers did not indicate to the participants that these were all views of the same room.

Measures

Overconfidence. As in Experiment 1, and following Sun et al. (2011), the responding variable was overconfidence: the difference between the participant's estimated trivia score and their actual trivia score. We collected an overconfidence score after each of the four trials, presenting participants with the following: "As accurately as possible, please estimate your score on that last trivia round out of ten."

Attention Checks. Throughout the experiment, we incorporated 10 attention checks, such that participants failing to read through the experiment instructions and tasks could be eliminated. For example, the following instructions would appear at random amid regular trivia questions: "Where in the human body is the stapedius muscle situated? If you are paying attention, please select "Ears." A) Europe B) Ears C) Television D) Seattle." We removed participants who scored 7 or lower out of 10.

Manipulation Checks. At the end of the experiment, participants went through three manipulation check questions to assess the level of embodiment and presence they experienced during the mental imagery prompts, as well as their confidence about their overall trivia performance (Appendix F).

Vividness of Visual Imagery Questionnaire 2 (VVIQ-2) (Marks, 1995). Participants were asked a series of questions to assess their visualization ability (see Appendix F).

Demographic Questionnaire. Following the VVIQ-2, participants were presented with a demographics questionnaire.

Deception Checks. During the debriefing, we collected participants' responses to a suspicion probe (Appendix F) asking if they had any guesses about the true purpose of the study. Following this, study subjects were debriefed on the real purpose of the study.

2.3 Results

Prior to analysis, we removed six responses for failing attention checks. We did not remove any participants on the basis of manipulation or suspicion checks.

Overconfidence

After reviewing the descriptive statistics, consistent with Experiment 1, participants in Experiment 2 typically *under*estimated their trivia performance, though slightly less so ($M = -1.14$, $SD = 2.41$). To mitigate order effects, we analyzed the mean overconfidence scores of repeated trials (such that we analyzed one mean score for both ascending mental imagery trials, both neutral mental imagery trials, and so on). Mean overconfidence scores are visualized in Figure 11.

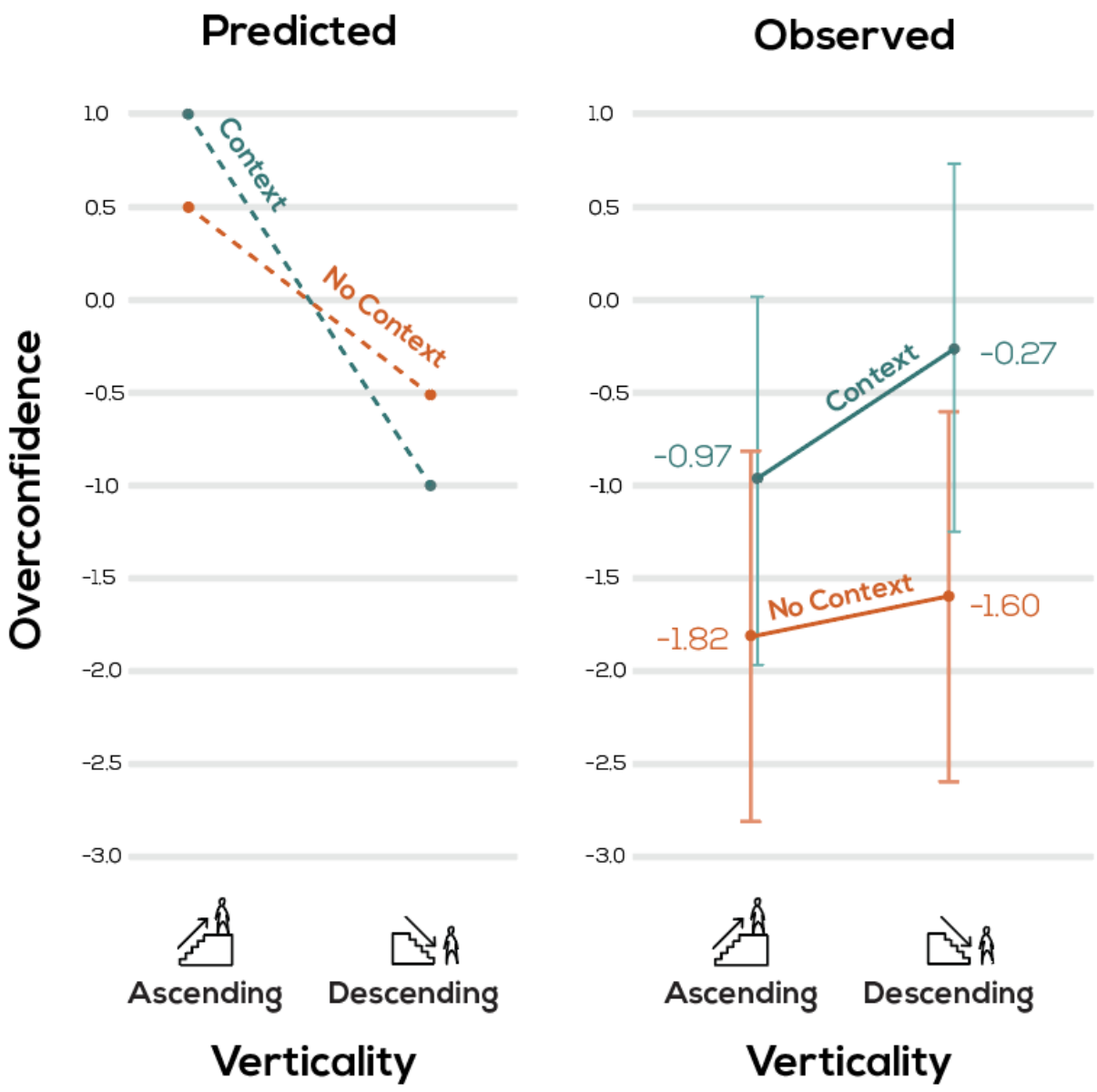

Figure 11. Graph of predicted vs mean overconfidence scores for Experiment 2. As we predicted, the Context Group had higher overconfidence scores, though this difference was not statistically significant.

There were no outliers in the data, as assessed by examination of studentized residuals for values greater than ±3. Overconfidence scores were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). There was no violation of the assumption of homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). Similarly, there was no violation of the assumption of homogeneity of

covariances, as assessed by Box's test of equality of covariance matrices (p = .069). A 2 x 2 mixed ANOVA was run with verticality as a within-subjects factor, context group as a between-subjects factor, VVIQ-2 as a covariate. Our hypothesis was that overconfidence scores would be higher in both ascending conditions; however, this hypothesis was not supported by the data. Controlling for VVIQ-2 score, there was no statistically significant interaction between verticality and context group, $F(1, 61)$ = 1.11, p = .491, partial η^2 = .008 (N = 64). There was a statistically significant difference in overconfidence for the main effect of verticality, but opposite to the predicted direction (overconfidence was *higher* in the *descending* conditions): $F(1, 61)$ = 4.64, p = .035, partial η^2 = .071. There was no main effect for confidence group $F(1, 61)$ = 2.02, p = .160, partial η^2 = .032.

VVIQ-2

A Pearson's product-moment correlation was run to assess the relationship between VVIQ-2 score and overconfidence in the ascending verticality condition. We predicted that a higher VVIQ-2 score (i.e., richer visualization ability) would be correlated with greater susceptibility to the metaphor of heightened verticality. In other words, we predicted that participants with clearer mental imagery would experience a stronger embodied metaphor effect when visualizing themselves ascending the stairs during the experiment. Preliminary analyses showed the relationship to be linear with both variables normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), and there were no outliers. However, our hypothesis was not supported, as there was no statistically significant correlation between VVIQ-2 score and overconfidence in ascending conditions, $r(62) = -.026$, $p = .839$.

2.4 Discussion

For experiment 2, we again attempted to replicate previous findings that higher verticality is associated with greater overconfidence. We predicted that participants would provide higher estimates of their trivia performance following mental imagery of *ascending* a staircase than they would after imagining *descending* the same staircase, and that including congruent verbal cues relating ascension to capability

would strengthen this effect. Counter to our predictions, we found evidence of greater overconfidence in the *descending* conditions. Our results did not support our hypothesis that contextual cues would strengthen the direction of this verticality effect, though the data did trend towards such a conclusion.

In contrast to Experiment 1, where the control measure was a neutral-verticality moving walkway, the control for Experiment 2 was *moving downwards*. Opposite to what we predicted, participants had greater overconfidence in the *descending* conditions. There are several possible explanations for these unexpected results: perhaps participants associated descending a set of stairs with tasks becoming easier; maybe the contradiction of the incongruent context cue was more memorable and therefore more impactful; or perhaps participants were compensating for a perceived effect by estimating their own performance more highly. While higher verticality is often associated with *better* in various contexts, *moving upwards* may not be. We call a difficult challenge an *uphill battle* and say, "It's all downhill from here," while confidently completing an easy task. (Confusing matters further, we use the same phrase, "It's all downhill from here," to describe a situation that is only going to get worse.)

We can also draw from film to speculate on potential unintended embodied metaphor effects. Many films and TV shows have featured the grand staircase trope (*Grand Staircase Entrance - TV Tropes*, n.d.), where a lead character descends a set of stairs to showcase beauty and / or a prestigious transformation. Most recently, the character Wednesday descends the stairs in episode four of the eponymously named series (Alpert et al., 2022). She appears striking in a new dress and hairstyle, captivating her peers as she enters the setting of the school ball. First popularized by Cinderella (Branagh, 1950), similar shots can be found in many other films and shows, such as My Fair Lady (Cukor, 1964), Anastasia (Goldman & Bluth, 1997), Harry Potter and the Goblet of Fire (Newell, 2005), and Bridgerton (Brownwell et al., 2020). In contrast, *ascending* a staircase is associated with a different trope in cinema: Ending by Ascending (*Ending By Ascending - TV Tropes*, n.d.). Often placed at the end of a show, imagery of characters ascending upwards is often associated with the afterlife or an otherwise uncertain future. For example, at the end of The Truman Show (Weir,

1998), Truman is shown escaping the confines of his reality show towards an unknown outside world by literally climbing a staircase leading into the sky (albeit a set wall painted to look like the sky). In Willy Wonka & the Chocolate Factory (Stuart, 1971), Charlie, his grandfather, and Willy Wonka are shown disappearing into the sky in a glass elevator, symbolizing unknowable adventures ahead. Titanic (Cameron, 1997) elegantly features both tropes: in the beginning, Rose, a high society girl, makes a grand entrance descending this ship's first class staircase; she imagines ascending those same steps in the final scene of the movie, to join her deceased lover who is waiting for her at the top. Though our predictions in Experiments 1 and 2 relied on the metaphor of UP = GOOD, a less prevalent metaphor of ascension representing uncertainty (we say something is "up in the air" if it is still undecided) might have overridden our results, leading to lower overconfidence in ascending conditions. Similarly, the atmosphere of grandeur associated with descending a large set of stairs could have caused participants to feel more overconfident in the descending conditions.

Future research could clarify these results of Experiment 2 by further investigating contextual nuances, measuring participants' overconfidence scores in response to real-world scenarios. For example, researchers could ask participants to imagine themselves at the end of a long day at work when ascending or descending the stairs. Or more simply, future investigations might implement a control condition where participants imagine themselves standing stationary in a flat room, avoiding any priming effects from the idea of movement itself.

General Discussion

This thesis opened with a thought experiment: we asked the reader to imagine donning a VR headset to stand atop a mountain in a virtual landscape, suggesting that such an experience would lead to *elevated* emotions. This was illustrative of the initial aims of this research; we sought to examine such an emotional outcome by empirically investigating the experience of VR through the lens of embodied metaphor theory. In Experiment 1 (Virtual Escalators), we had participants take part in multiple trivia rounds while encountering a moving walkway or an escalator, through either mental imagery, video, or virtual embodiment. We found no significant differences in participants' overconfidence between medium conditions. In our follow-up study, Experiment 2 (Imaginary Staircases) we again tested our ideas about verticality and explored the potential influence of context. Specifically, we investigated the effect of congruent and incongruent verbal cues relating the embodied metaphor or verticality to the concept of personal capability. We asked participants to rate their trivia performance after imagining ascending or descending a staircase, either with or without additional verbal cues. We found a significant difference in participants' overconfidence between conditions, though in a direction opposite to what we predicted: heightened overconfidence in the descending condition. We found no main effect for contextual cues.

While we failed to find evidence for a verticality effect from heightened / ascending verticality, it is important to note also that the results presented in this thesis cannot provide evidence for *the absence* of a verticality effect either. There may very well be a verticality effect, but Experiment 1 was either designed with too many drawbacks or was too underpowered (or some combination thereof) to detect such an effect. Overall, there are a variety of possible issues with the designs of the experiments presented in this thesis. Some of these problems have already been discussed, particularly the challenge of designing an adequate control condition. Another possible issue for both studies might be the reliability of overconfidence as a meaningful measure: while a number of researchers have taken an interest in verticality, the only instance of overconfidence as a responding variable in a study on

verticality (that we are aware of) was in the Sun et al. 2011 study. Our measure of overconfidence (estimated trivia performance minus actual trivia performance) focused on individual participants, meaning that we did not ask participants to compare their performance to that of their unseen peers, a more common approach in overconfidence studies. Similarly, overconfidence itself is nuanced. The mechanism through which it occurs in the brain operates differently depending on whether or not an individual's self-esteem is threatened (Beer, 2014), such that any attempt to measure overconfidence may very well be a matter of measuring two entirely different cognitive processes. Overall, overconfidence itself—though a seemingly simple measure—comes in many forms and is often studied incorrectly: Olsson argues that much of the literature describing observed overconfidence is actually a matter of statistical error (2014).

Alternatively, Experiment 1 may have suffered due to an inherent difference between VR and the real world when experiencing embodied metaphors. Though VR has become a popular tool for simulation, there are limits to the similarities between how people respond to the real world and how they respond to VR. These limits are surprisingly under-researched, likely due to the difficulty of comparing VR to the real world in experimental settings. For example, recording participants' physiological responses to a speedboat ride in VR is relatively straightforward, but safely organizing actual speedboat rides for any meaningful quantity of participants would surely prove taxing. On the other hand, a researcher might reasonably design an experiment where participants ascend stairs in both the real world and VR. We ourselves could not investigate that comparison due to pandemic restrictions, but future research of that nature would help establish whether our results were a consequence of VR's limitations, errors in experiment design, or even a repercussion of broader issues in embodied metaphor research.

As we discussed briefly in the introduction, studies on specific embodied metaphors have failed to replicate, fueling controversy in the field. For example, Lynott et al. (2014) were unable to reproduce the results of Williams and Bargh's highly cited 2008 experiments finding that experiencing physical warmth (e.g., by holding a hot beverage or a warm gel pack) causes participants to perceive other

people as *warmer* in an interpersonal sense (the embodied metaphor of *social warmth*). Citing expectancy effects, Lynottet et al. speculated that Williams and Bargh might have unintentionally influenced participants through subtle cues during their experiments in order to find such an effect (see Klein et al., 2012). Future studies in the field of embodied metaphor research would benefit from more double-blind studies, as would future iterations of the experiments presented in this thesis.

Aside from possible researcher bias, there are other global issues in embodied cognition research. As Jeannette Littlemore describes in her 2019 book, "Metaphors in the Mind," more research is needed to understand the effects of embodied metaphors when they are encountered in genuine communication circumstances as opposed to laboratory settings. The artificial environments in which most lab experiments have been carried out have likely distorted the way in which individuals have responded to embodied metaphors. In that vein, the experiments in this thesis have been designed with a degree of sterility: the environment of Experiment 1 was possibly simplified to the point of austerity and neither Experiment 1 nor Experiment 2 reflected any kind of real-world scenarios. The 2011 Sun et al. study, in contrast, was designed around students on campus taking a test (obviously, a common situation), and the 2015 Slepian et al. study targeted students already naturally navigating campus staircases. Perhaps, as we attempted to explore in Experiment 2, real world context does matter, though further research is needed to fully understand the extent to which that might be true.

In our experiments, we used the common approach of general knowledge trivia to assess overconfidence. As we previously discussed, participants did not generally enjoy the trivia and felt *under*confident. In line with exploring embodied metaphor in a more contextualized sense, future studies could utilize tasks with higher stakes or greater sense of relevance to the participants. For example, researchers could measure outcomes based on goal-setting construal level (as in Ostinelli et al., 2014) or cash-based betting rewards (Blavatskyy, 2009).

Overall, being influenced by one's environment is likely a nuanced experience, where many factors matter, both in the environment, the individual themselves, and the context in which they have found themselves there. This may explain the lack of

published studies on universal environmental effects. While specific effects in specific contexts have been found—for example, gold-clad restaurants encourage tipping (Lee et al., 2018) and office cubicles facilitate focused work (Roberts et al., 2019)—there is little-to-no research indicating that a particular environmental attribute (e.g., higher ceilings or cluttered surfaces) has a consistent effect on people *across situational contexts*. As Littlemore elaborates, embodied metaphor researchers have sought universal effects when perhaps the nature of embodied cognition is inherently deeply contextual and, further to that, deeply varied (2019).

Inspired by the use of metaphor in therapeutic and educational applications, we chose to approach our investigation from the angle of embodied metaphor research. However, our results indicate that an alternate approach is worth exploring in the future: investigating metaphors in VR not as unconscious influences but as conscious tools. Though we began to approach such ideas in Experiment 2 by incorporating contextual statement cues into mental imagery prompts, more work is needed to understand how embodied metaphors are experienced in VR when the participant is aware of the metaphor and its implications. For example, future research could reference Deliberate Metaphor Theory (DMT), wherein an individual intentionally uses a metaphor to communicate an idea (Steen, 2015, 2017). Though this theory fits within the umbrella of Conceptual Metaphor Theory in that the understanding of one domain is mapped onto another, DMT is concerned with the *deliberate* cross-mapping of a metaphor *as* a metaphor. For example, Steen argues that the phrase, "Imagine your brain as a house filled with lights," is an example of *deliberate* metaphorical language while saying that someone is "in love," is *not* (2015). In the case of the first phrase, "Why did you use that metaphor?" would be an appropriate follow-up question, whereas such a question would not make sense in response to someone being described simply as, "in love."

Future research might explore and even evaluate VR for the *deliberate* use of embodied metaphors. For example, researchers could extend Spangenberger et al.'s 2022 study where participants embodied a tree in VR. Spangenberger et al. compared the resulting sense of nature-relatedness between these participants and those in a view-only condition, but did not find a stronger experimental effect in the VR

condition. Future research could test this tree embodiment experience as a deliberate metaphorical calming exercise, asking participants to emotionally ground themselves *like a tree*. Researchers could then measure their heart rates, comparing the results to the view-only group. This would parallel a more plausible real-world application of metaphorical language (envisioning a tree while meditating).

From a methodological perspective, we pioneered a new workflow in the course of this research, utilizing Altspace VR to facilitate virtual embodied experiment appointments. These were generally successful in reducing the novelty effect so often compromising VR research. Online studies have dramatically impacted psychological research due to the relative ease with which large sample sizes can be surveyed. Similarly, as VR becomes more widespread, there is a possibility for mass scale psychological study methods wherein participants expect consistency of remuneration and comfort when participating regularly in surveys. Attention checks are a difficult problem with web browser-based online surveys (even in our own study 2, we had to filter out participants who failed attention checks) and perhaps VR studies lend themselves to greater participant focus.

The ultimate aim of our research was to better understand VR, an emerging technology with the potential to make a meaningful impact on people's lives. As an ongoing VR-funding boom continues, developers are rushing to build content for VR; such developers should strive to leverage research on VR's unique capabilities to build meaningful, enduring applications. Though the findings presented in this thesis do not specifically provide evidence for a verticality effect in VR as we hypothesized, Experiment 2 results indicated a verticality effect in the opposite direction of what we predicted. There is a need for further research on embodied metaphors, both to replicate existing studies and to explore metaphors grounded in everyday life contexts. The results of these two experiments indicate that higher verticality is not necessarily correlated with higher overconfidence, but that, when it exists at all, the influence of embodied metaphor on cognition is nuanced.

References

Alpert, K. (Writer), Gough, A. (Writer), & Burton, T. (Director). (2022). Woe What a Night (Season 1, Episode 4) [Television series episode]. In K. Alpert, G. Berman, T. Burton, J. Glickman, C. González Vargas, A. Gough, T. Harper, N. Iannelli, K. Lafferty, M. Millar, D. Minkowski, K. Miserocchi, A. Mittman, C. Pepelea, S. Stark, N. Testa, T. Williams (Executive Producers), *Wednesday*. MGM Television.

Avanzini, P., Fabbri-Destro, M., Dalla Volta, R., Daprati, E., Rizzolatti, G., & Cantalupo, G. (2012). The dynamics of sensorimotor cortical oscillations during the observation of hand movements: an EEG study. *PLoS One*, *7*(5), e37534.

Beer, J. S. (2014, October). Exaggerated Positivity in Self-Evaluation: A Social Neuroscience Approach to Reconciling the Role of Self-esteem Protection and Cognitive Bias. *Social and Personality Psychology Compass*, *8*(10), 583–594. https://doi.org/10.1111/spc3.12133

Blavatskyy, P. R. (2009). Betting on own knowledge: Experimental test of overconfidence. *Journal of Risk and Uncertainty*, *38*(1), 39-49.

Branagh, K. (2015). *Cinderella*. Walt Disney Studios Motion Pictures.

Brownwell, J. (Writer), Cohan-Miccio, L. (Writer), McDonald, A. (Writer), & Verica, T. (Director). (2022). Art of the Swoon (Season 1, Episode 3) [Television series episode]. In B. Beers, S. Rhimes, C. Van Dusen (Executive Producers), *Bridgerton*. Shondaland CVD Productions.

Cameron, J. (1997). *Titanic*. Paramount Pictures.

Carassa, A., Morganti, F., & Tirassa, M (2004). Movement, Action, and Situation: Presence in Virtual Environments. *EXPLORING THE SENSE OF PRESENCE*, 7.

Cian, L. (2017). Verticality and Conceptual Metaphors: A Systematic Review. *Journal of the Association for Consumer Research*, 2(4), 444–459. https://doi.org/10.1086/694082

Cukor, G. (1964). *My Fair Lady*. Warner Bros.

Cummings, J. J., & Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media psychology*, *19*(2), 272-309.

Dufner, M., Denissen, J. J., Van Zalk, M., Matthes, B., Meeus, W. H., van Aken, M. A., & Sedikides, C. (2012). Positive intelligence illusions: On the relation between intellectual self-enhancement and psychological adjustment. *Journal of*

Personality, *80*(3), 537-572.

Earp, B. D., Everett, J. A., Madva, E. N., & Hamlin, J. K. (2014). Out, damned spot: Can the "Macbeth Effect" be replicated?. *Basic and Applied Social Psychology*, *36*(1), 91-98.

Ending by Ascending - TV Tropes. (n.d.). TV Tropes. Retrieved December 22, 2022, from https://tvtropes.org/pmwiki/pmwiki.php/Main/EndingByAscending

Goldman, G., & Bluth, D. (1997). *Anastasia*. Twentieth Century Fox.

Golf-Papez, M., & Veer, E. (2017). Don't feed the trolling: rethinking how online trolling is being defined and combated. *Journal of Marketing Management*, *33*(15-16), 1336-1354.

Goodie, A. S. (2005). The role of perceived control and overconfidence in pathological gambling. *Journal of gambling studies*, *21*(4), 481-502.

Gorini, A., Capideville, C. S., De Leo, G., Mantovani, F., & Riva, G. (2011). The role of immersion and narrative in mediated presence: the virtual hospital experience. *Cyberpsychology, Behavior, and Social Networking*, *14*(3), 99-105.

Grand Staircase Entrance - TV Tropes. (n.d.). TV Tropes. Retrieved December 22, 2022, from https://tvtropes.org/pmwiki/pmwiki.php/Main/GrandStaircaseEntrance

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2020, July 11). Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1–32. https://doi.org/10.1007/s40692-020-00169-2

Howard, M. C., & Gutworth, M. B. (2020, January). A meta-analysis of virtual reality training programs for social skill development. *Computers & Education*, *144*, 103707. https://doi.org/10.1016/j.compedu.2019.103707

Huang, W. (2020). *Investigating the novelty effect in virtual reality on stem learning* (Doctoral dissertation, Arizona State University).

IBM Corp. (2013). IBM SPSS Statistics for Windows (Version 22.0) [Computer software]. IBM Corp.

Johnson, D. D., & Fowler, J. H. (2011). The evolution of overconfidence. *Nature*, *477*(7364), 317-320.

Kaplan, A. D., Cruit, J., Endsley, M., Beers, S. M., Sawyer, B. D., & Hancock, P. A. (2020, February 24). The Effects of Virtual Reality, Augmented Reality, and Mixed

Reality as Training Enhancement Methods: A Meta-Analysis. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *63*(4), 706–726. https://doi.org/10.1177/0018720820904229

Karimpur, H., & Hamburger, K. (2018). A rat in the sewer: How mental imagery interacts with object recognition. *PloS one*, *13*(3), e0194227.

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, *3*(3), 203-220.

Kisker, J., Gruber, T., & Schöne, B. (2021). Behavioral realism and lifelike psychophysiological responses in virtual reality by the example of a height exposure. *Psychological research*, *85*(1), 68-81.

Klein, O., Doyen, S., Leys, C., Magalhães de Saldanha da Gama, P. A., Miller, S., Questienne, L., & Cleeremans, A. (2012). Low hopes, high expectations: Expectancy effects and the replicability of behavioral experiments. *Perspectives on Psychological Science*, *7*(6), 572-584.

Klimmt, C., & Vorderer, P. (2003). Media psychology "is not yet there": Introducing theories on media entertainment to the presence debate. *Presence*, *12*(4), 346-359.

Kompa, N. (2017). The myth of embodied metaphor. *Croatian Journal of Philosophy*, *17*(2 (50)), 195-210.

Lakens, D. (2014). Grounding social embodiment. *Social Cognition*, *32*(Supplement), 168.

Lakoff, G., & Johnson, M. (2008). *Metaphors we live by*. University of Chicago Press.

Lee, N. Y., Noble, S. M., & Biswas, D. (2018). Hey big spender! A golden (color) atmospheric effect on tipping behavior. *Journal of the Academy of Marketing Science*, *46*(2), 317-337.

Lee, S. W., & Schwarz, N. (2011). Wiping the slate clean: Psychological consequences of physical cleansing. *Current directions in psychological science*, *20*(5), 307-311.

Leung, A. K. Y., Kim, S., Polman, E., Ong, L. S., Qiu, L., Goncalo, J. A., & Sanchez-Burks, J. (2012). Embodied metaphors and creative "acts". *Psychological science*, *23*(5), 502-509.

Littlemore, J. (2019, July 27). *Metaphors in the Mind - Sources of Variation in Embodied Metaphor*. Cambridge University Press. https://doi.org/10.1017/9781108241441

Lynott, D., Corker, K. S., Wortman, J., Connell, L., Donnellan, M. B., Lucas, R. E., & O'Brien, K. (2014). Replication of "Experiencing physical warmth promotes interpersonal warmth" by Williams and Bargh (2008). *Social Psychology*.

Manjoo, F. (2022, November 4). *My sad, lonely, expensive adventures in Zuckerberg's V.R.* The New York Times. Retrieved November 23, 2022, from https://www.nytimes.com/2022/11/04/opinion/facebook-meta-zuckerberg-virtual-reality.html

Marks, D. F. (1995). New directions for mental imagery research. *Journal of Mental Imagery, 19*, 153-167.

Martin, J., Cummings, A. L., & Hallberg, E. T. (1992). Therapists' intentional use of metaphor: Memorability, clinical impact, and possible epistemic/motivational functions. *Journal of Consulting and Clinical Psychology*, *60*(1), 143.

Moore DA, Healy PJ (2008) The trouble with overconfidence. Psychological Review 115: 502–517.

Murphy, S. C., Barlow, F. K., & von Hippel, W. (2018). A longitudinal test of three theories of overconfidence. *Social Psychological and Personality Science*, *9*(3), 353-363.

Newell, M. (2005). *Harry Potter and the Goblet of Fire*. Warner Bros.

Olsson, H. (2014). Measuring overconfidence: Methodological problems and statistical artifacts. *Journal of Business Research*, *67*(8), 1766-1770.

Ostinelli, M., Luna, D., & Ringberg, T. (2014). When up brings you down: The effects of imagined vertical movements on motivation, performance, and consumer behavior. *Journal of Consumer Psychology*, 24(2), 271–283. https://doi.org/10.1016/j.jcps.2013.12.001

Park, M. J., Kim, D. J., Lee, U., Na, E. J., & Jeon, H. J. (2019, July 19). A Literature Overview of Virtual Reality (VR) in Treatment of Psychiatric Disorders: Recent Advances and Limitations. *Frontiers in Psychiatry*, *10*. https://doi.org/10.3389/fpsyt.2019.00505

Plous, S. (1993). *The psychology of judgment and decision making*. Mcgraw-Hill Book Company.

Riva, G., Davide, F., & IJsselsteijn, W. A. (2003). *Being there: Concepts, effects and measurements of user presence in synthetic environments*. Ios Press.

Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D., ... & Alcañiz, M. (2007). Affective interactions using virtual reality: the link between

presence and emotions. *Cyberpsychology & behavior*, *10*(1), 45-56.

Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive brain research*, *3*(2), 131-141.

Roberts, A. C., Yap, H. S., Kwok, K. W., Car, J., Soh, C. K., & Christopoulos, G. I. (2019). The cubicle deconstructed: Simple visual enclosure improves perseverance. *Journal of Environmental Psychology*, *63*, 60-73.

Rosch, E., Thompson, E. and Varela, F. (1991). *The Embodied Mind: Cognitive Science and Human Experience.* MIT Press.

Rosenbaum. (2022, November 17). *Why Reality Labs will keep spending billions even as Meta makes the biggest cuts in its history*. CNBC. Retrieved December 8, 2022, from https://www.cnbc.com/2022/11/17/why-reality-labs-will-keep-losing-billions-even-as-meta-makes-big-cuts.html

Silvestre-López, A. J., Pinazo, D., & Barrós-Lorcertales, A. (2021). Metaphor can influence meta-thinking and affective levels in guided meditation. *Current Psychology*, 1-13.

Slater, M., Usoh, M., & Steed, A. (1995). Taking steps: the influence of a walking technique on presence in virtual reality. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *2*(3), 201-219.

Slepian, M. L., Masicampo, E. J., & Ambady, N. (2015). Cognition from on high and down low: Verticality and construal level. *Journal of Personality and Social Psychology*, *108*(1), 1–17. https://doi.org/10.1037/a0038265

Spangenberger, P., Geiger, S. M., & Freytag, S. C. (2022). Becoming nature: effects of embodying a tree in immersive virtual reality on nature relatedness. *Scientific Reports*, *12*(1), 1-11.

Steen, G. (2015). Developing, testing and interpreting deliberate metaphor theory. *Journal of pragmatics*, *90*, 67-72.

Steen, G. (2017). Deliberate Metaphor Theory: Basic assumptions, main tenets, urgent issues. *Intercultural Pragmatics*, *14*(1), 1-24.

Stuart, M. (1971). *Willy Wonka & The Chocolate Factory*. Paramount Pictures.

Sun, Y., Wang, F., & Li, S. (2011). Higher Height, Higher Ability: Judgment Confidence as a Function of Spatial Height Perception. *PLoS ONE*, *6*(7), e22125. https://doi.org/10.1371/journal.pone.0022125

Sweetser, P., Rogalewicz, Z., & Li, Q. (2019, November). Understanding enjoyment in

VR games with GameFlow. In *25th ACM Symposium on Virtual Reality Software and Technology* (pp. 1-2).

Tay, D. (2013). Metaphor in psychotherapy. *Metaphor in Psychotherapy*, 1-219.

Taylor, S. E., & Brown, J. D. (1988). Illusion and well-being: a social psychological perspective on mental health. *Psychological bulletin*, *103*(2), 193.

Taylor, S. E., Lerner, J. S., Sherman, D. K., Sage, R. M., & McDowell, N. K. (2003). Are self-enhancing cognitions associated with healthy or unhealthy biological profiles?. *Journal of personality and social psychology*, *85*(4), 605.

Weir, P. (1998). *The Truman Show*. Paramount Pictures.

Williams, L. E., & Bargh, J. A. (2008). Experiencing physical warmth promotes interpersonal warmth. *Science*, *322*(5901), 606-607.

Wilson, V. E., & Peper, E. (2004). The effects of upright and slumped postures on the recall of positive and negative thoughts. *Applied psychophysiology and biofeedback*, *29*(3), 189-195.

Witmer, B.G. & Singer. M.J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence : Teleoperators and Virtual Environments*, 7(3), 225-240.

Wood, J. V., Elaine Perunovic, W. Q., & Lee, J. W. (2009). Positive self-statements: Power for some, peril for others. *Psychological Science*, *20*(7), 860-866.

Wu, B., Yu, X., & Gu, X. (2020, September 8). Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. *British Journal of Educational Technology*, *51*(6), 1991–2005. https://doi.org/10.1111/bjet.13023

Ye, J. (2022, November 1). *China aims to ship 25 million virtual reality devices by 2026*. Reuters. Retrieved November 23, 2022, from https://www.reuters.com/technology/china-aims-ship-25-million-virtual-reality-devices-by-2026-2022-11-01/

Zhong, C. B., & Liljenquist, K. (2006). Washing away your sins: Threatened morality and physical cleansing. *Science*, *313*(5792), 1451-1452.

Appendices

Appendix A - A Primer on AltspaceVR

AltspaceVR is an online platform where users can gather in 3D environments, communicating primarily over voice chat and embodied gestures. Users create accounts, customize avatars (Figure A1), and visit different worlds and events to interact with the Altspace community. Altspace, as a social VR platform (and not, for example, a first person shooter game) has a relatively diverse population, although Altspace does not report any data on its user demographics.

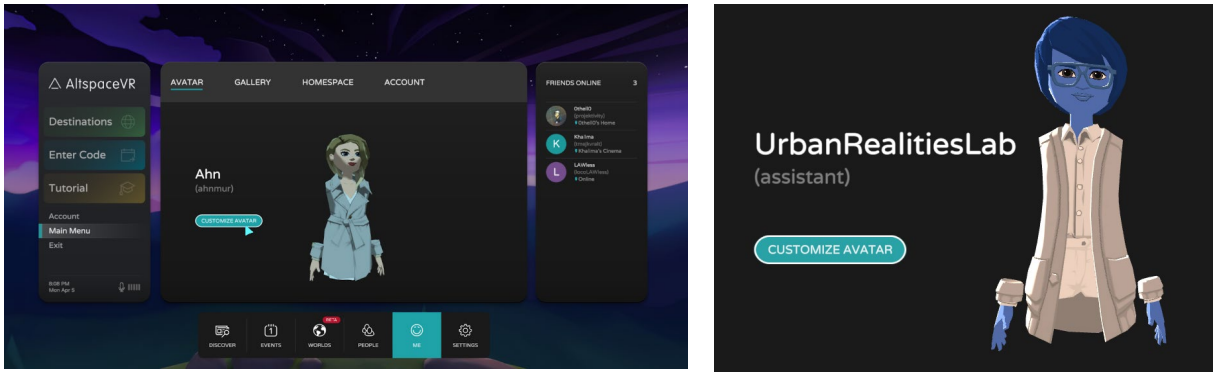

Figure A1. Avatar embodiment in AltspaceVR.
Left: AltspaceVR users have extensive options to customize their avatars.
Right: The research team used a consistent avatar, designed to be as gender and race neutral as possible.

The Urban Realities Lab has a virtual location in AltspaceVR where the study information events were held (Figure A2). All appointments for Experiment 1 took place in a custom-built experiment world, where research assistants led participants through a series of rooms containing the different experiment stimuli (see Figure 3).

Unlike undergraduate research participants, who are motivated to complete studies in order to receive course credit, participants drawn from the public require different incentives. Participants in this study were given a modest remuneration ($10 for an hour-long commitment). It is possible that a larger amount of money might have drawn in a greater number of participants. However, many of the participants reported that they were not motivated by the remuneration at all, and that they were participating out of curiosity and an overall passion for VR. As such, we are inclined to speculate that the length of the experiment itself was an issue. An hour long experiment, though not atypical, can be overwhelming as a VR experience. Though most participants had no issues with this, we cannot know how many potential participants were deterred from signing up due to the length of the study.

Figure A2. Recruitment strategies.
Left: Banner used to advertise the recruitment events (as well as the study itself).
Right: The virtual location of The Urban Realities Lab in AltspaceVR used to host recruitment events.

More broadly, high attrition rates in multi-part online studies often pose a challenge to researchers. We faced this within our study as a consequence of our four part sign-up system: though we had 206 potential participants complete our initial consent form, we only had 111 potential participants finish a pre-experiment demographic survey, and only 75 participants scheduled an experiment appointment and actually showed up. This is the nature of conducting research with the public, but finding ways to streamline the consent process and demographic collection so that participants could begin the experiment without any homework ahead of time might have led to a larger sample size. After eliminating participants who felt sick or uncomfortable, our final sample size was 72.

There is a tradeoff between collecting more data from fewer participants and collecting less data from a greater number of participants, and it is hard to say if small tweaks to the experiment flow might have made a big difference to our final sample size. There may also be limitations to AltspaceVR as a platform for conducting research. Utilizing a more heavily populated VR platform might have led to a larger sample size, but come with its own drawbacks. VRChat, for example, is a social VR platform with a larger user base, but its population tends to be younger (below the age of consent) and generally less professional (VRChat is known for trolling[11]).

Ultimately, a whole new platform for conducting research in VR would be a great benefit to researchers. Beyond its utility for those studying the effects of VR itself, such a platform would be useful for any research that would benefit from great attention. Media multitasking during online studies limits their viability, yet it is often impossible to measure and even hard to prevent. In contrast, participants wearing a headset are inherently less distracted. Ideally, such a platform would allow for asynchronous study participation as well, incorporating a library of user interface shortcuts for researchers to draw from.

[11] Trolling refers to online behaviour where a user intentionally bothers another user / group of users in order to elicit an emotional reaction (Golf-Papez & Veer, 2017).

Appendix B - Trivia Questions

To ensure that most participants could answer some—but not all—of the questions, we included a range of topics, including: literature, culture, music, geography, world history, sports, movies, and science. To alleviate fatigue, questions were curated to be short and concise.

Similarly, every set of questions included:

Experiment 1	Experiment 2
• 4 easy questions • 3 medium-difficulty questions • 3 challenging questions	• 11 easy questions • 6 medium-difficulty questions • 3 challenging questions

There will be 180 questions in total, and the order in which participants are asked the questions will be block randomized.

A sample round of 10 trivia questions:

"Please answer the following ten trivia questions as quickly as you can. This is just a distractor task, so don't worry too much about your accuracy, and try to answer as quickly as you can. If you don't know or aren't sure, simply guess A, B, C, or D."
(This reminder will be stated for the first few trials.)

Question	**Category**	**Difficulty**
Which color is NOT one of the rings on the Olympic flag? A) green B) yellow C) black D) orange Answer: orange	Sports	Easy
Which of these planets *doesn't* have rings? A) Jupiter B) Venus C) Saturn D) Neptune Answer: Venus	Science	Medium
In Twenty Thousand Leagues Under the Sea, what was the name of the warship in which Captain Nemo sailed? A) Basillus B) Nautilus C) Remolus D) Black Pearl Answer: Nautilus.	Literature	Easy
In the movie Rocky, what was the name of Rocky Balboa's dog? A) Butkus B) Sly C) Rawhide D) Champ Answer: Butkus	Movies	Medium

Beyoncé's song, “Crazy in Love” was released in what year? A) 2003 B) 2019 C) 1997 D) 2010 Answer: 2003	Music	Hard
What is the second largest island in the world? A) Baffin B) New Guinea C) Madagascar D) Greenland Answer: New Guinea	Geography	Medium
What was the first nation to give women the right to vote? A) Saudi Arabia B) Finland C) New Zealand D) Australia Answer: New Zealand	World History	Hard
What is parasol a kind of? A) Umbrella B) Footwear C) Bracelet D) Chemical Answer: Umbrella.	Miscellaneous	Easy
In literature, which author used the pseudonym Isaac Bickerstaff? A) Mark Twain B) Jonathan Swift C) Roald Dahl D) Charles Dickens Answer: Jonathan Swift	Literature	Hard
Which Disney character famously leaves a glass slipper behind at a royal ball? A) Pocahontas B) Sleeping Beauty C) Cinderella D) Elsa Answer: Cinderella	Culture	Easy

Appendix C - Immersive Tendencies Questionnaire (ITQ)

(Witmer & Singer, 1996)

1. Do you easily become deeply involved in movies or tv dramas?

Never Occasionally Often

2. Do you ever become so involved in a television program or book that people have problems getting your attention?

Never Occasionally Often

3. How mentally alert do you feel at the present time?

Never Occasionally Often

4. Do you ever become so involved in a movie that you are not aware of things happening around you?

Never Occasionally Often

5. How frequently do you find yourself closely identifying with the characters in a story line?

Never Occasionally Often

6. Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?

Never Occasionally Often

7. How physically fit do you feel today?

Not Fit Moderately Fit Extremely Fit

8. How good are you at blocking out external distractions when you are involved in something?

Not very good Somewhat good Very good

9. When watching sports, do you ever become so involved in the game that you react as if you were one of the players?

Never Occasionally Often

10. Do you ever become so involved in a daydream that you are not aware of things happening around you?

Never Occasionally Often

11. Do you ever have dreams that are so real that you feel disoriented when you awake?

Never Occasionally Often

12. When playing sports, do you become so involved in the game that you lose track of time?

Never Occasionally Often

13. How well do you concentrate on enjoyable activities?

Never Occasionally Often

14. How often do you play arcade or video games? (OFTEN should be taken to mean every day or every two days, on average.)

Never Occasionally Often

15. Have you ever gotten excited during a chase or fight scene on TV or in the movies?

Never Occasionally Often

16. Have you ever gotten scared by something happening on a TV show or in a movie?

Never Occasionally Often

17. Have you ever remained apprehensive or fearful long after watching a scary movie?

Never Occasionally Often

18. Do you ever become so involved in doing something that you lose all track of time?

Never Occasionally Often

Appendix D - Experiment 1 Checks

Manipulation Checks

The following questions were asked verbally. Participants were presented an image to remind them of the response options (not at all / a little bit / moderately / severely).

In the trials where you imagined a room, how embodied did you feel?
[not at all / a little bit / moderately / very much]

In the trials where you imagined a room, did you feel a sense of "being there"?
[not at all / a little bit / moderately / very much]

In the trials where you watched a video depicting a room, how embodied did you feel?
[not at all / a little bit / moderately / very much]

In the trials where you watched a video depicting a room, did you feel a sense of "being there"?
[not at all / a little bit / moderately / very much]

In the trials where you controlled your avatar as it moved across the room, how embodied did you feel?
[not at all / a little bit / moderately / very much]

In the trials where you controlled your avatar as it moved across the room, did you feel a sense of "being there"?
[not at all / a little bit / moderately / very much]

Simulator Sickness Checks

Adapted from Kennedy et al., 1993

The following questions were asked verbally. Participants were shown an image of the matrix to remind them of the response options (none / slight / moderate / severe).

Researcher: "I will list a series of symptoms. For each symptom, please verbally answer how much that symptom affected your performance on the tasks during the experiment."

General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe

Eye strain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Salivation increasing	None	Slight	Moderate	Severe
Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
Fullness of the Head	None	Slight	Moderate	Severe
Blurred vision	None	Slight	Moderate	Severe
Dizziness with eyes open	None	Slight	Moderate	Severe
Dizziness with eyes closed	None	Slight	Moderate	Severe
Vertigo*	None	Slight	Moderate	Severe
Stomach awareness**	None	Slight	Moderate	Severe
Burping	None	Slight	Moderate	Severe

* Vertigo is experienced as loss of orientation with respect to vertical upright.
** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Suspicion Checks

Researchers verbally probed for suspicion during the debriefing using the following script:

“When people participate in psychology studies, they sometimes become suspicious if they feel that the research has a hidden purpose. Did you experience any feelings of suspicion about anything that you encountered during the survey?
If you did feel any suspicion throughout the survey, do you think it affected any of your responses?
Do you have any guesses about what the study is really about? We would be interested in hearing any ideas you might have. Did anything seem strange or odd to you?”

Appendix E - Experiment 2 Guided Imagery Scripts

Group A (***not*** given context for the mental imagery prompts):

Ascending	"Close your eyes. Think of the image you were shown of a set of stairs. Now, imagine yourself at the foot of that staircase. Picture looking up as you prepare to ascend. Now, imagine yourself stepping upwards as you ascend that set of stairs. You go up and up. Step by step. You reach the midpoint. Imagine that you continue ascending. [Pause.] Now picture yourself reaching the top of the set of stairs, and looking back at the steps you just ascended. [Pause.] You may now open your eyes and proceed with the experiment."
Descending	"Close your eyes. Think of the image you were shown of a set of stairs. Now, imagine yourself at the top of that staircase. Picture looking down as you prepare to descend. Now, imagine yourself stepping downwards as you descend that set of stairs. You go down and down. Step by step. You reach the midpoint. Imagine that you continue descending. [Pause.] Now picture yourself reaching the bottom of the set of stairs, and looking back at the steps you just descended. [Pause.] You may now open your eyes and proceed with the experiment."

Group B (given context for the mental imagery prompts):

Congruent / Ascending	"Close your eyes. Think of the image you were shown of a set of stairs. Now, imagine yourself at the foot of that staircase. Picture looking up as you prepare to ascend. Now, imagine yourself stepping upwards as you ascend that set of stairs. You go up and up. Step by step. *As you ascend, imagine yourself becoming more and more capable with every step*. You reach the midpoint. Imagine that you continue ascending. Now picture yourself reaching the top of the set of stairs. Looking back at the steps you just ascended, reflect on how capable you are. You may now open your eyes and proceed with the experiment."
Incongruent / Descending	"Close your eyes. Think of the image you were shown of a set of stairs. Now, imagine yourself at the top of that staircase. Picture looking down as you prepare to descend. Now, imagine yourself stepping downwards as you descend that set of stairs. You go down and down. Step by step. *As you descend, imagine yourself becoming more and more capable with every step*. You reach the midpoint. Imagine that you continue descending. Now picture yourself reaching the bottom of the set of stairs. Looking back at the steps you just descended, reflect on how capable you are. You may now open your eyes and proceed with the experiment."

Appendix F - Experiment 2 Checks

Manipulation Checks

When you imagined ascending or descending stairs, how embodied did you feel?
[not at all / a little bit / moderately / very much]

When you imagined ascending or descending stairs, did you feel a sense of "being there"?
[not at all / a little bit / moderately / very much]

Overall, how confident were you about your performance in the four trivia rounds?
[not confident at all, a little confident, moderately confident, very confident]

Vividness of Visual Imagery Questionnaire 2 (VVIQ-2)

(Marks, 1995)

Visual imagery refers to the ability to visualize, that is, the ability to form mental pictures, or to "see in the minds' eye". Marked individual differences have been found in the strength and clarity of reported visual imagery and these differences are of considerable psychological interest.

The aim of this test is to determine the vividness of your visual imagery. The items of the test will possibly bring certain images to your mind. You are asked to rate the vividness of each image by reference to the 5-point scale given below: No image at all/ Vague and dim/ Moderately clear and vivid/ Reasonably clear and vivid/ Perfectly clear & vivid as if I was actually seeing it. Familiarize yourself with the different categories on the rating scale. Throughout the test, refer to the rating scale when judging the vividness of each item separately, independent of how you may have done other items. Complete all items for images obtained with your eyes CLOSED.

In answering items 1 to 4, think of some relative or friend whom you frequently see and consider carefully the picture that comes to your mind's eye.

1. The exact contour of face, head, shoulders and body.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

2. Characteristic poses of head, attitudes of body etc.

		Moderately clear	Reasonably clear	Perfectly clear & vivid as if I was

No image at all	Vague and dim	and vivid	and vivid	actually seeing it

3. The precise carriage, length of step, etc. in walking.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

4. The different colours worn in some familiar clothes.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

In answering item 5 to 8, think of the items mentioned in the following questions and rate the vividness of your imagination.

5. The sun is rising above the horizon into a hazy sky.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

6. The sky clears and surrounds the sun with blueness.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

7. Clouds. A storm blows up, with flashes of lighting.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

8. A rainbow appears.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

In answering items 9 to 12, think of the front of a shop which you often go to. Consider the picture that comes before your mind's eye.

9. The overall appearance of the shop from the opposite side of the road.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

10. A window display including colours, shape and details of individual items for sale.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

11. You are near the entrance. The colour, shape and details of the door.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

12. You enter the shop and go to the counter. The counter assist serves you. Money changes hands.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

In answering items 13 to 16, think of a country scene which involves trees, mountains and a lake.

13. The contours of the landscape.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

14. The colour and shape of the trees.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

15. The colour and shape of the lake.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

16. A strong wind blows on the trees and on the lake causing waves.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

In answering items 17 to 20, think of being driven in a fast-moving automobile by a relative or friend along a major highway. Consider the pictures that comes into your mind's eye.

17. You observe the heavy traffic travelling at maximum speed around your car. The overall appearance of vehicles, their colours, sizes and shapes.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

18. Your car accelerates to overtake the traffic directly in front of you. You see an urgent expression on the face of the driver and the people in the other vehicles as you pass.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

19. A large truck is flashing its headlights directly behind. Your car quickly moves over to let the truck pass. The driver signals with a friendly wave.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

20. You see a broken- down vehicle beside the road. Its lights are flashing. The driver is looking concerned and she is using a mobile phone.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

In answering items 21 to 24, think of a beach by the ocean on a warm summer's day. Consider the picture that comes before you minds' eye.

21. The overall appearance and colour of the water, surf, and sky.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

22. Bathers are swimming and splashing about in the water. Some are playing with a brightly coloured beach ball.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

23. An ocean liner crosses the horizon. It leaves a trail of smoke in the blue sky.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

24. A beautiful air balloon appears with four people aboard. The balloon drifts past you, almost directly overhead. The passengers wave and smile. You wave and smile back at them.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

In answering items 25 to 28, think of a railway station. Consider the picture that comes before you mind's eye.

25. The overall appearance of the station viewed in front of the main entrance.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

26. You walk into the station. The colour, shape and details of the entrance hall.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

27. You approach the ticket office, go to a vacant counter and purchase your ticket.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

28. You walk to the platform and observe other passengers and the railway lines. A train arrives. You climb aboard.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

Finally, in answering items 29 to 32, think of a garden with lawns, bushes, flowers and shrubs. Consider the picture that comes before your mind's eye.

29. The overall appearance and design of the garden.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

30. The colour and shape of the bushes and shrubs.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

31. The colour and appearance of the flowers.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

32. Some birds fly down onto the lawn and start pecking for food.

No image at all	Vague and dim	Moderately clear and vivid	Reasonably clear and vivid	Perfectly clear & vivid as if I was actually seeing it

Suspicion Checks

Participants were presented with the following probe during the debriefing:

"When people participate in psychology studies, they sometimes become suspicious if they feel that the research has a hidden purpose. Did you experience any feelings of suspicion about anything that you encountered during the survey? If so, do you think it affected any of your responses? Do you have any guesses about what the study is really about? We would be interested in hearing any ideas you might have."