Lucid Virtual Dreaming: Antecedents and Consequents of Virtual Lucidity during Virtual Threat

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ABSTRACT

Here we report the first empirical findings on *virtual lucidity* (VL), a new construct similar to lucidity during dreaming, but regarding awareness that one is having a virtual experience. VL concerns the depth and breadth of this awareness, as well as the extent it affords regulatory monitoring and control. To study VL, we adapted a measure from lucid dreaming research to assess whether more VL predicted lower fear, but not less enjoyment, during a virtual reality (VR) threat scenario of walking, and being asked to step off, a wooden plank seemingly high above a city. We examined predictors of VL and related outcomes across a community sample and lucid dream trainees at a meditation retreat center. In line with hypotheses, higher VL predicted less fear, more enjoyment, and greater likelihood of stepping off the plank. Moreover, a number of dispositional factors predicted greater VL and lower fear. Lucid dream retreatants, engaged in a contemplative practice called *illusory form yoga*, experienced more VL and less fear compared to nonretreatants, with marginally higher likelihood of stepping off the plank. Finally, VL mediated all significant relations between predictors and outcomes. Results held controlling for presence or fear of heights. We discuss the potential validity and utility of VL, its relation to presence, and examples of how it may inform the development and application of VR and related technologies.

Keywords: Lucid dreaming, meditation, mindfulness, presence, virtual lucidity, virtual reality.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, Augmented, and Virtual Realities; J.4 [Computer Applications]: Social and Behavioral Sciences—Psychology

1 INTRODUCTION

The power of virtual reality (VR) to create a convincing sense of being present in virtual environments has been of longstanding interest [28,32,33]. Often termed *presence*, this sense is not unlike the feeling of being elsewhere during nightly dreams, wherein individuals are unaware (i.e., non-lucid) that the vivid experience of the dream is largely a construction of their sleeping mind, brain, and body [14,15]. Yet in sleep, exceptions to this unawareness do exist in the form of *lucid dreams*, defined as dreams in which an individual is aware that they are dreaming during the dream [19]. Rather than uniformly detracting from presence, such awareness can enhance felt presence in, and engagement with, the dream. Thus, with dream lucidity, awareness that one is dreaming can coincide with more presence, as well as scaffold more conscious responding to the dream. Lucidity can enable the dreamer to modulate and monitor engagement with the dream according to their broader goals (e.g., stop running away from a scary dream character and instead turn to ask the dream character a question).

Similarly, during a given virtual experience, there can be variation in the extent that one is aware of the virtuality of one's experience. Moreover, this variation in *virtual lucidity* (VL; [24]) is not simply variation in presence. Just as one can enhance awareness that one is dreaming and yet feel very present in the dream, one may heighten awareness that one is having a virtual experience and yet feel very present in the virtual environment [24]. Analogous to the example above in which dream lucidity allows the dreamer to consciously face a threatening dream character, VL may allow individuals to face threatening virtual scenarios with less fear.

According to this theoretical understanding of VL, this first empirical study on VL investigated its relation to presence, enjoyment, fear, and behavior in the context of a virtual threat scenario involving fear of heights. The study was designed to provide initial evidence for the existence of VL, explore its links to other relevant constructs, and examine some of its possible antecedents and consequents. We think this is important in order to establish a basis for further investigation of VL, including its potential to inform the development and application of VR and related technologies. Regarding this potential, we offer examples in the next section, after first introducing and defining VL further.

2 UNDERSTANDING VIRTUAL LUCIDITY

A noted feature of presence in VR is its seemingly paradoxical nature, in the sense that it can coincide with conceptual awareness of the virtuality of one's experience [28,31]. Yet research on presence has pertained primarily to the degree individuals respond to the virtual experience as though it were *not* virtual, despite conceptual recognition otherwise. Consistent with its distinction from presence, VL goes beyond mere conceptual recognition of the virtuality of virtual experience. This is similar to dream lucidity, for which there exists considerable variation in not only the depth and breadth of lucid awareness, but also in the extent such awareness affords more conscious engagement with the dream.

Motivated by this parallel context of lucid dreaming, VL is defined here as *explicit recognition of the virtual aspects of one's current experience, together with regulatory affordances provided by this recognition* [24]. Put another way, when one experiences VL, they are both aware of what aspects of their current experience are virtual *and* able to leverage this awareness to better regulate their thoughts, feelings, and actions. This differs from presence because, although presence can occur *despite* conceptual awareness that one's experience is virtual [28,31], such conceptual awareness is the starting point of *what defines* VL. Presence primarily concerns responses evoked as though VR was *not* virtual, while VL primarily concerns the extent of awareness that one's experience *is* virtual, as well as how much this awareness affords regulatory control.

How might VL afford regulatory control in VR? VR can strongly elicit automatic responses to virtual experience as though it were not virtual at cognitive, emotional, and behavioral levels (cf.

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[22]). With VL, recognizing what aspects of experience are virtual informs regulatory monitoring and/or modulation of these automatic responses. A high degree of VL therefore entails ongoing sensitivity to internal and external cues that may signal the need for allocating cognitive resources to respond from lucid awareness, rather than habitual reactivity [24]. Accordingly, a measure for VL need not only capture the depth and breadth of awareness that one's experience is virtual, but also how much this awareness is leveraged to enhance regulation of cognition, emotion, and behavior.

A cursory look at VL may construe it as counter to efforts for increasing immersion to advance VR technology and its various applications. After all, aims of technological advancement in VR (e.g., higher frame-rates) often focus on generating VR experience that more reliably evokes presence [28]. Yet as noted, enhancing VL need not imply decreasing presence in virtual environments. To the contrary, depending on one's goals, VL may lead to increased presence in VR—albeit not less awareness of its virtuality.

In view of that, here we briefly describe three examples of how VL may inform the development and application of VR. Although VL may similarly inform development and application of other technology (e.g., augmented and mixed reality), we present VR examples here since that is the focus of this initial empirical study. First, we think VL offers avenues for VR users to modify the psychological context in which they use VR. For example, if reliable methods for enhancing VL are found, perhaps related to those explored here, users could engage them to modify their experience of VR generally. Relatedly, if VL affords greater regulatory control in VR, developers may consider incorporating mechanisms that promote VL alongside presence, such as regular reminders about the virtual nature of one's experience. Finally, neural correlates of VL, once established, could serve as input for brain-computer interfaces that dynamically update VR content, improving experience and performance, or for training (cf. [21]). For example, such an interface could allow VL to mirror other aspects of lucid dreaming by offering more control over, and realism of, the virtual world as VL increases.

2.1 Virtual Lucidity and Emotion Regulation

Viewing VL through the lens of emotion regulation theory may be helpful for understanding how it could support regulated responding to virtual experience more generally. Specifically, the *process model of emotion regulation* [10] provides a valuable theoretical framework for understanding VL and its consequences. This model builds upon the *modal model of emotion*, which views emotion generation as an unfolding process triggered by a situation that influences attention, appraisal, and subsequently a coordinated response [10].

One of the most commonly studied emotion regulation strategies is *reappraisal*, involving reinterpretation of emotion-related events to alter their emotional effects. Reappraisal could occur in a variety of ways, such as reappraising the photograph of a bloody crime scene as having an ending where the murder is solved (i.e., *changing its future consequences*), or considering that the photograph is staged (i.e., *challenging its reality*; [23]). In the context of understanding VL, this latter reappraisal strategy is particularly well-suited to regulate effectively in the context of VR [24]. This is because, during VR, reappraising virtual experience as virtual is clearly more truthful than not doing so.

Despite the potential for such reappraisal in VL to regulate emotional responses to VR, VL need not dampen emotional engagement. This is important for understanding VL's distinction from a mere reduction in virtual presence, since prior research supports the view that emotional responses evoked by VR can heighten presence, and higher presence may also increase emotional responses to VR [26]. Further, higher presence may relate to greater enjoyment of VR generally [37], so one might predict that VL would relate to lower enjoyment of VR. However, if VL is supportive of more conscious emotion regulation during VR, then it could afford down-regulation of aversive emotional responses without detracting from overall enjoyment.

2.2 Psychological Factors for Virtual Lucidity

The potential of VL to enhance conscious responding to VR represents a psychological, as opposed to technological, route to altering user experience in VR. Prior research has explored relations between existing psychological dispositions and VR user experience (e.g., [18,27]), as well as manipulating the content of VR according to psychological principles (e.g., [26,32]). Less attention has been paid to factors by which VR users may themselves modify the psychological context in which they relate with VR. This is important because identifying such factors may have broad and immediate applicability to user experience of existing VR technology (e.g., brief interventions that boost VL).

Toward this end, the parallel context of lucid dreaming can be leveraged to identify relevant factors. Indeed, there is a long history of lucid dream research focused on identifying factors and practices that individuals may engage to increase dream lucidity [20]. Such research has identified potentially modifiable dispositional factors related to more lucidity during dreams, including dispositional mindfulness [3]. Mindfulness is defined as *an adaptive mental state characterized by intentional, receptive attention to the present moment* [3,17], and has been considered a state during waking that shares characteristics with lucidity during dreaming [34,35]. This is because both mindfulness and lucidity are distinguished by more conscious, and less automatic, responding to one's immediate experience [35]. Although we expect mindfulness in VR can support the initiation and maintenance of VL, VL is distinguishable from mindfulness because it goes beyond intentional, receptive attention. Specifically, VL includes clear discernment of the virtual aspects one's current experience. Nonetheless, if lucidity during dreaming is related to the function of similar processes during waking [35], then lucid dream occurrence may also predict VL.

Established relations between lucidity in dreams and mindfulness in waking is also important in the context of manipulating VL, for both research and application purposes. A variety of meditation practices support the cultivation of mindfulness, and accordingly, meditation experience itself has been shown to predict lucid dream frequency [8,34]. Meditation practices may support VL by enhancing the functioning of core cognitive processes involved in regulatory processing generally [11], and this may occur through not only long-term training, but also following even brief periods of meditation practice [41]. Thus, studying the effects of meditation on VL may reveal brief mental training activities that are readily accessible to VR users. A meditation practice often used in research is a breath-focused meditation commonly referred to as *mindfulness meditation* [17]. Consistent with its potential regulatory benefits in VR, a quasi-experimental study found that mindfulness meditation predicted lower anxiety and heart rate during stressful VR experience [6].

There also exist meditation practices in contemplative traditions that more specifically target the development of lucidity, which allows one to better recognize the illusory aspects of current experience. One such practice is *illusory form yoga* [16]. Illusory form yoga is considered the diurnal correlate to lucid dreaming in the Tibetan Buddhist tradition. According to the Tibetan Buddhist view, reality is illusionlike (ultimately "empty" of inherent existence) [4], so this practice acts as a template for perceiving reality in this way. Specifically, through the practice of *impure illusory form,* an individual continually reminds themselves that what they are perceiving during the day is like a dream. Importantly, this view is not about psychological dissociation or escapism [16]. To the contrary, the aim is to dereify experience and thereby challenge habitual ways of perceiving, which can promote more conscious engagement moment by moment. This dereification may then naturally extend into the night, and can be useful for apprehending the dream state [16]. A bidirectional or reciprocating relationship is then established between diurnal and nocturnal practice: illusory form yoga supports lucid dreaming, and lucid dreaming, in a positive feedback loop, then supports the practice of illusory form [16]. With sustained practice, impure illusory form matures into *perfectly pure illusory form,* when one actually perceives the world's dreamlike nature. If illusory form supports such awareness generally, across both dream and waking states, then its practice in the context of VR may similarly support VL.

2.3 The Present Research

One kind of virtual scenario commonly related to virtual presence involves the appearance of height [1,25], for example, in walking on a narrow beam raised above the ground [1]. To examine some potential antecedents and consequents of VL, we relied here on a height-related virtual scenario that is readily available on consumer VR platforms. Specifically, the VR scenario entails walking the length of a wooden plank seemingly located high above a city and looking around. Additionally for this study, participants were prompted with a choice of whether to step off the plank and apparently fall toward the ground.

As the first empirical investigation of VL, we primarily targeted factors identified as relevant to lucidity during dreams, and especially those that may be readily modifiable. Given the usefulness of emotion regulation theory for understanding VL, we focused on two emotional outcome variables, namely fear and enjoyment. We also assessed the behavioral outcome of whether participants chose to step off the plank when prompted. To maximize the representativeness of our sample for predictor variables of lucid dreaming and meditation experience, our study sample included students and community members with varying levels of meditation experience, as well as lucid dream trainees at a meditation retreat center. This diverse sample was also important given our interest in the formal contemplative practice of illusory form yoga, which may require voluntary engagement in the context of teachings on its view and overall purpose.

Consistent with theory and prior empirical research discussed above, we expected that more VL would predict lower fear without detracting from enjoyment. We further expected that higher VL would predict greater likelihood of stepping off the plank. We hypothesized that dispositional mindfulness, lucid dream frequency, and meditation experience would predict VL, lower fear, and greater likelihood of stepping off. Regarding the potential to manipulate VL, we randomly assigned community sample participants to engage in either audio guided mindfulness meditation or an audiobook control on a neutral topic prior to VR, expecting that mindfulness meditation would enhance VL, lower fear, and increase the likelihood of stepping off. A third condition comprised lucid dream trainees who listened an audio guided illusory form yoga practice. We aimed to compare lucid dream trainees with both mindfulness meditation and control groups, expecting higher VL, lower fear, and more likelihood of stepping off for this group of lucid dream trainees. Finally, consistent with its role in affording regulation, we expected VL to mediate significant relations between predictor and outcome variables.

3 Methods

3.1 Participants

Participants comprised both a community sample and a group of lucid dream trainees at Shambhala Mountain Center, a meditation retreat center in Red Feather Lakes, CO. For the community sample, participants were recruited using advertisements for an opportunity to try immersive VR, while the group of lucid dream trainees were notified of the opportunity to participate in VR research only after for registering for the retreat. The three-day retreat was designed to introduce a variety of techniques and practices for increasing the frequency of depth of lucid dreams, including the practice of illusory form yoga studied here, along with lectures, meditation, experiential exercises, and group discussion. Prospective retreat participants received an email prior to arriving at the retreat center, and were provided further details upon arriving. Interested participants were then invited to complete study procedures individually during a scheduled session.

All participants were informed that our interest was in learning activities that may relate to people's sense of physicality in VR environments. Each participant was screened for age (18 to 60 years), lack of previous direct experience with immersive VR, and native English language speaking. Additionally, participants had no current neurological, significant medical, or psychiatric condition. Using a software-based randomizer, all qualifying community sample participants were randomized to either audio guided mindfulness meditation or an audiobook control. Of the 61 qualifying participants, 3 were excluded from analyses due to technical or procedural error, leaving 28 for mindfulness meditation, and 30 for the control group. Of the 25 retreatants qualifying for participation, 3 were excluded due to technical or procedural error, leaving 22 participants. Thus, the total number of participants across conditions was 80. Of these 80 participants, 56.25% were male and 44.75% were female. Regarding race/ethnicity, 77.5% identified as White, 3.75% as Latino/Hispanic, 1.25% as Asian Indian, 1.25% as Black/African American (non-Hispanic), 1.25% as Puerto Rican, 1.25%, and 13.75% as more than one race/ethnicity. The average age was 34, with a range from 19-60 years.

3.2 Materials

3.2.1 Self-report Measures

In a battery of self-report measures, participants completed the following study-relevant scales and items:

Virtual lucidity. A six-item scale was adapted from a measurement approach used in lucid dreaming research [36] to assess VL following VR experience. Specifically, we adapted the measure to capture VL at cognitive, emotional, and perceptual levels. Three items assessed the presence of lucidity (e.g., "I was very cognitively aware of the fact that I was in virtual reality. It was *easier* to deliberately not react, to control my reactions, or to observe passively the course of the virtual experience with this cognitive awareness.”). For the two additional items, “cognitive” was replaced by “emotional” or “perceptual.” Since an absence of VL may be more apparent to participants than its presence (cf. [19]), three items likewise assessed VL through its absence (e.g., “I was somewhat tricked into thinking the virtual experience was real. It was *harder* to deliberately not react, to control my reactions, or to observe passively the course of the virtual experience based on this.”). For the two additional items, “thinking” was replaced by “feeling” or “perceiving.” Participants reported using a 7-point scale from 1 (Never) to 7 (Always), and the latter three items were reverse coded prior to averaging. Sample Cronbach’s α = .89.

Fear of heights. To account for the influence of dispositional fear of heights in analyses, the Acrophobia Questionnaire (AQ; [5]) was used to measure anxiety and avoidance of height situations. The 20-item scale describes various height situations and asks for ratings of anxiety and avoidance. Sample Cronbach’s α = .91.

Virtual presence. A version of the 6-item Slater-Usoh-Steed (SUS; [38]) questionnaire was used to evaluate presence. Specifically, to provide quantitative assessment across all SUS items, corresponding 7-point scales were provided for each. For example, participants responded from 1 (Real world) to 7 (Virtual reality) to the item, “During the time of the virtual experience, which was strongest on the whole, your sense of being in the virtual reality, or of being in the real world?” Sample Cronbach’s α = .65.

Mindfulness. A basic form of dispositional mindfulness was measured by the 15-item Mindful Attention Awareness Scale (MAAS; [3]). The MAAS has been used extensively in prior research on mindfulness, and is designed to assess variation in attentiveness to the present moment (sample item: “I find myself doing things without paying attention”). Higher scores reflect higher mindfulness (1= *almost always* to 6 = *almost never*). Sample Cronbach’s α = .84.

Lucid dream frequency. Lucid dream frequency was assessed with a single item shown to have high retest reliability in prior research [36]. Following a brief definition of lucid dreaming (“During lucid dreaming, one is—while dreaming—aware of the fact that one is dreaming. It is possible to deliberately wake up or to control the dream action or to observe passively the course of the dream with this awareness”; [30]), the item asks “How often do you experience so-called lucid dreams?” An 8-point scale ranged from “Never” to “Several times a week.”

Meditation experience. Self-report items were used to assess breadth and depth of prior meditation experience, since each may capture overlapping yet distinct variation in contemplative training. Breadth of meditation experience was assessed by the number of practice styles experienced out of a list of 7 commonly practiced meditation styles, while depth of experience was assessed according to amount of retreat days (“Approximately how many days of formal contemplative practice retreat have you done?”). Since amount of time since first meditating may qualify these indices, an additional item asked, “About how long ago did you engage in any contemplative practice for the first time?” (0 = None; 1 = Less than six months; 2 = Between six months and 1 year; 3 = Between 1 and 2 years; 4 = Between 2 and 4 years; 5 = Between 4 and 8 years; 6 = Between 8 and 16 years; 7 = more than 16 years).

Fear, anxiety, and distress. To assess fear at various points during the VR experience, the Subjective Units of Distress Scale (SUDS; [40]) was administered immediately after removing the VR headset. Scale instructions asked participants to imagine they have a “distress thermometer,” and measures level of anxiety and fear on a 10-point scale, expressed in increments of 10 (0 = Totally relaxed; 50 = Moderate anxiety/distress, uncomfortable but can continue to perform; 100 = Highest distress/fear/anxiety/discomfort that you have ever felt). Our specific interest was in SUDS ratings during the most intense moments of the VR experience.

Enjoyment/fun. Overall degree of enjoyment/fun was assessed with a single item on an adapted 9-item state affect scale (“To what degree were you experiencing the following emotions during the virtual experience?”; [7]). Participants responded to each emotion listed, including “Enjoyment/fun,” on a 7-point scale (0 = Not at all; 6 = Extremely).

3.2.2 Virtual Reality Headset and Experience

The HTC Vive system, with an OLED display, 2160 x 1220 resolution, 90 Hz refresh rate, and external Lighthouse room-scale tracking system, was used to deliver the virtual experience titled, *Richie’s Plank Experience* (Toast VR; https://toast.gg). Of note, *Richie’s Plank* is a VR experience readily available for both the Vive and Oculus Rift headsets. In the virtual scenario, participants experience beginning at ground level, pressing an elevator button, and riding the elevator briefly before its doors open. Next, they are seemingly located about 80 stories above the city with only a small wooden plank in front of them. This virtual plank was calibrated to match a real wooden plank’s parameters, an option included with *Richie’s Plank* (see Figure 1). Precise motion tracking ensures coupling between participant’s movements along the virtual and actual wooden planks. Additional elements (e.g., helicopter flying by) are included in the virtual cityscape environment.

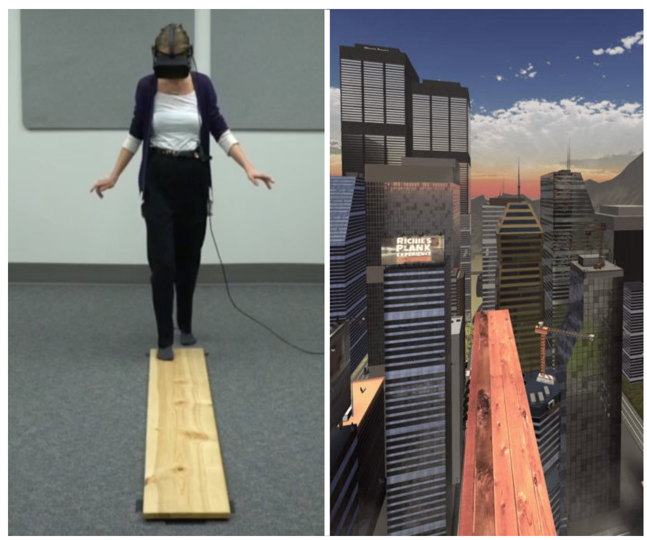

Figure 1: Experiment environment included real wooden plank (left). A screenshot from the version of *Richie’s Plank Experience* used in the study (right); *Richie’s Plank Experience* has since been updated, including graphical improvements.

3.3 Procedures

This initial study on VL relied on a combined approach involving questionnaires, experimentation, and cross-sectional investigation. To maximize the representativeness of our sample for predictor variables of lucid dreaming and meditation experience, our study sample included students and community members with varying levels of meditation experience, as well as lucid dream trainees at a meditation retreat center (see Participants section for more details about the retreat). Although the study was conducted in two different locations, all study instructions and experimental procedures were standardized across conditions.

Following informed consent, all participants completed a battery of self-report questionnaires on a computer. Participants were then guided to another room to complete the VR scenario. Introductory remarks provided all participants the same cover story regarding our interest in how different learning activities affect people's sense of physicality in virtual environments. Next, just prior to VR headset application, participants listened to a 7-minute audio recording with eyes closed for the "learning portion." Each audio featured a male voice, but differed in content according to condition. Participants randomly assigned to the audiobook condition listened to a book read aloud on a neutral topic, namely about history of the town Selborne [39], used as a control in similar mindfulness research. Participants in the mindfulness meditation condition listened to a guided mindfulness meditation, used in similar prior research, involving focused attention on respiratory sensations. Finally, participants in the illusory form yoga condition listened to a guided illusory form yoga practice, instructing them to attend to illusory aspects of experience on an ongoing basis.

Immediately after the audio recording, all participants were instructed to keep their eyes closed and the VR headset was applied and adjusted. Participants then completed the virtual scenario (see Virtual Reality Headset and Experience). Throughout the scenario, assistants walked alongside participants and delivered the following prompts to guide them through the experience: Once elevator doors opened, research assistants instructed, "Please go ahead and walk the distance of the wooden board in front of you in a straight line. Be careful not to step off, but do walk all the way to the edge." After participants reached the plank's edge, they were asked, "Please take a few moments to look around." After about 10 seconds, the next prompt was delivered, "You may choose not to, but if you'd like to, when you're ready, take a step forward off the board." Finally, if participants had not yet stepped off, a final prompt was delivered, "Again, it is your decision whether you want to step off or not. If you choose not to step forward off the board in the next 10 seconds, we will then remove the headset." After headset removal, participants were guided to a computer for another set of measures, starting with SUDS ratings.

3.4 Data Preparation and Analytic Approach

Both SPSS (Version 22) and SAS (Version 9.4) were used to conduct statistical analyses. To meet assumptions of normality, a natural log transformation was conducted for days spent on meditation retreat. For SUDS analyses, we focused on the subset of ratings that elicited the strongest emotional responses during pilot testing. Specifically, we averaged ratings across the three items that spanned standing on the plank after being asked to step off, stepping off the plank, and seemingly falling. As expected, not all participants chose to step off, resulting in missing SUDS observations for some participants (N = 8). Given the relevance of these observations, we used related SUDS observations from just prior to discontinuing [37]. We also conducted sensitivity analyses without these observations, which resulted in a highly similar pattern of findings, so we report analyses from the full sample. Regression analyses were used for relations between predictor and outcome variables, logistic regression involving the Firth penalized likelihood method was used to examine predictors of stepping off the plank or not [13], and the PROCESS bootstrapping plugin (Model 4; [9]) was used for assessing meditation by VL (5000 resamples, 95% bias corrected confidence intervals).

4 Results

4.1 Preliminary Analyses

Regression was used to analyze relations between outcomes and the demographic variables of gender, race/ethnicity, and age. None of these relations were significant (*ps* > 0.30), and so were not analyzed further. We assessed whether condition (mindfulness meditation, audiobook control, or illusory form yoga) was significantly associated with relevant predictor variables, finding that it was not predictive of lucid dream frequency (LDF), dispositional mindfulness (MAAS), depth/breadth of meditation experience (ME), nor fear of heights (AQ). Age was significantly higher in our retreat (i.e., illusory form yoga) condition, but since age was not correlated with other relevant variables, we excluded it from analyses. Preliminary analyses also found that both AQ (p = .023) and SUS presence scores (p = .008) predicted VL, as well as SUDS distress scores (AQ: p = .021; SUS: p = .054). AQ also predicted enjoyment/fun (AQ: p = .002). Therefore, after initial tests of relations between predictor and outcome variables, multiple regressions included either AQ and SUS as control variables to assess potential influence on results. Since results were highly similar when controlling for either AQ and SUS, we report results from these subsequent analyses only when dissimilar.

4.2 Direct Relations between Self-report Predictors and Outcome Variables

Across all three conditions, relations between self-report predictors and continuous outcome variables were assessed in separate regression analyses (see Table 1). Regarding VL, the pattern of relations with both SUDS and enjoyment/fun supported hypotheses. Results also supported hypotheses regarding lucid dream frequency and dispositional mindfulness. Results for meditation experience revealed mixed support, with only breadth predicting VL. Regarding emotions, both breadth and depth of meditation experience predicted less distress (SUDS), without differences in enjoyment/fun.

Table 1: Relations between Predictors and Emotional Outcomes

Predictor	VL *β, p*-value	SUDS *β, p*-value	Enjoyment/fun *β, p*-value
VL	--	-.64, p < .001	.38, p < .001
SUS	-.28, p = .008	.22, p = .054	-.09, p = .409
AQ	-.24, p = .024	.26, p = .021	-.30, p = .004
LDF	.22, p = .038	-.29, p = .010	.13, p = .232
MAAS	.25, p = .020	-.31, p = .005	.01, p = .908
ME breadth[1]	.26, p = .029[2]	-.34, p = .006	.15, p = .216
ME depth[1]	.19, p = .084	-.28, p = .018	-.17, p = .152

Note. VL = Virtual lucidity; LDF = Lucid dream frequency; MAAS = Mindful Attention Awareness Scale; ME = Meditation experience; SUDS = Subjective Units of Distress Scale; [1]Controlling for time since first engaging in contemplative practice; [2]After controlling for AQ, p > .05.

Whether participants chose to step off the plank was analyzed using logistic regression. Due to a small sample size for logistic regression and the rarity of *not* stepping off (N = 8), the Firth penalized likelihood method was used [13]. In support of hypotheses, VL predicted greater likelihood of stepping off, and results held after controlling for SUS or AQ, which both predicted less likelihood of stepping off. Table 2 summarizes these findings.

Table 2: Relations between Predictors and Behavioral Outcome

Predictor	Step Off Plank? (0 = Yes; 1 = No) OR (CI); Model χ^2, *p*-value
VL	.34 (.15, .78); 9.65, *p* = .001
SUS	2.32 (.97, 5.50); 4.20, *p* = .056
AQ	3.57 (1.36, 9.40); 7.94, *p* = .009
LDF	.95 (.63, 1.42); .07, *p* = .790
MAAS	1.28 (.38, 4.29); .16, *p* = .687
ME breadth[1]	.70 (.45, 1.09); 2.54, *p* = .119
ME depth[1]	.95 (.61, 1.48); .23, *p* = .887

Note. OR = Odds Ratio; CI = 95% Confidence Interval; VL = Virtual lucidity; LDF = Lucid dream frequency; MAAS = Mindful Attention Awareness Scale; ME = Meditation experience; [1]Controlling for time since first engaging in contemplative practice.

4.3 Condition Differences

An initial comparison of mindfulness versus audiobook control revealed that mindfulness meditation did not significantly affect VL, SUDS, nor enjoyment/fun (*p*s > .80). We therefore combined these conditions for comparison with illusory form yoga. Results revealed that illusory form yoga had higher VL (β = .26, *p* = .014) and lower SUDS (β = -.32, *p* = .004), with no difference in enjoyment/fun (β = .02, *p* = .863; see Figure 2). Regarding stepping off the plank, a chi-square test of independence found that illusory form yoga trainees were marginally more likely to step off, χ^2(1, N = 80) = 3.37, *p* = .066. All trainees chose to step off, while an equal number (N =4) chose not to step off in each of the other conditions.

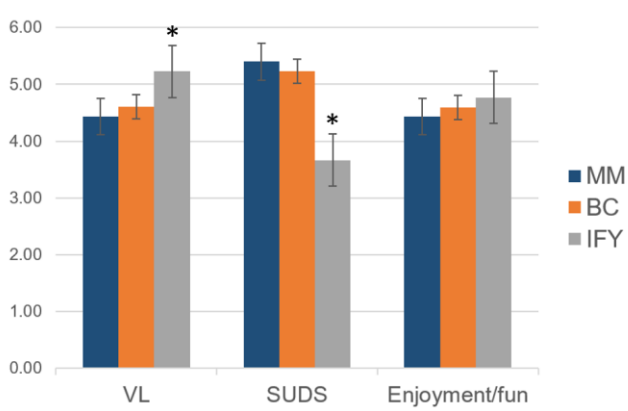

Figure 2: MM = Mindfulness meditation; BC = Audiobook control; IFY = Illusory form yoga; VL = Virtual Lucidity; SUDS = Subjective Units of Distress Scale. *Indicates that, compared with MM and BC, IFY had significantly higher VL and lower SUDS. There were no significant differences in enjoyment/fun.

4.4 Mediation Analyses

We next analyzed mediation by VL of relations between predictors and SUDS ratings, with significant mediation evident if the confidence interval (CI) of the indirect effect does not contain zero. First, regarding LDF, VL mediated relations with SUDS (b = -.163, 95% CI = [-.362, 0.016]). The relation between MAAS and SUDS was also significantly mediated by VL (b = -.654, 95% CI = [-1.265, -.237]). Regarding meditation experience, VL significantly mediated the relation between breadth of meditation experience and SUDS (b = -.235, 95% CI = [-.445, -.066]). Finally, for the relation between condition (engagement in illusory form yoga versus mindfulness/audiobook control) and outcomes, VL was a significant mediator between condition and SUDS (b = -.802, 95% CI = [-1.596, -.129]), as well as whether participants chose to step off the plank (b = -.905, 95% CI = [-2.385, -.0365]).

5 Discussion

The study of factors influencing people's sense of presence in virtual environments has been of central interest to VR researchers, and has undoubtedly shaped advancements in VR technology. Yet investigation on this topic has been driven primarily by interest in nonconscious responses to VR as though it were *not* virtual, such as at the level of automatic emotional and physiological processes (e.g., [2,30]). In contrast, VL is a new construct that pertains to variation in conscious recognition that one is having a virtual experience, as well as degree of regulatory affordance provided by this recognition [24]. As the first investigation of VL, our primary goals were to establish relations with factors identified in the parallel context of lucid dreaming research, particularly those that VR users and researchers may adapt to modulate VL. We also aimed to assess regulatory benefits of VL in domains of emotion and behavior during a virtual threat scenario that elicits fear of heights. Specifically, we examined VL in the context of a virtual scenario that entailed walking, and then being asked to step off, a wooden plank seemingly located high above a city.

Regarding lucidity during VR, we hypothesized that higher VL would predict reduced fear without detracting from overall enjoyment. We observed that VL predicted lower fear and, interestingly, greater enjoyment/fun. Although we did not predict VL would be positively related to enjoyment/fun, this finding similarly supports the view that VL is distinct from reduced presence, which may lower enjoyment [37]. Further, in line with expectations that VL affords behavioral regulation to VR as though it were not virtual, VL predicted greater likelihood of stepping off the plank. VL also mediated significant relations between all predictors and the outcome variables of fear and stepping off the plank, consistent with its theorized role in affording regulatory monitoring and/or modulation of responses during VR. These and other primary results held after controlling for presence or fear of heights, adding further support to VL as a distinct factor in VR user experience and behavior.

Regarding self-reported predictors, lucid dream frequency, dispositional mindfulness, and meditation experience predicted VL and lower fear, with no difference in enjoyment. The relation between VL and lucid dream frequency supports the view that cognitive factors supportive of lucidity during dreaming may be transferable to the novel context of VR. Relatedly, dispositional mindfulness, which centrally concerns variation in conscious attention and awareness, has been posited as a process during waking experience that shares features with lucidity during dreams [35], and formal meditation practices generally aim to increase the frequency, depth, and continuity of such mindful awareness. Consistent with the potential of mindful cognition to support lucidity, the overall pattern of results showed that both higher dispositional mindfulness and an index of formal meditation experience predicted higher VL and lower fear. Further, VL mediated the relationship between experienced fear and both dispositional mindfulness and breadth of meditation experience. Together with traditional views on contemplative training (cf. [4]), these findings suggest that an underexplored mechanism for at least some benefits of mindfulness and related contemplative practices may be their scaffolding of lucid awareness (i.e., recognition of illusory aspects of current experience, together with regulatory affordances provided by this recognition).

In the present study, however, a brief mindfulness meditation did not alter VL, emotional experience, nor likelihood of stepping off the plank relative to an active control group. It is noteworthy that the study was conducted in a unique study population in which almost all (93%) of community sample participants reported prior meditation experience. Therefore, it is possible that a brief mindfulness exercise was an insufficient "dosage" for eliciting differences in mindfulness during a novel situation, namely one's first experience of VR. Lack of a manipulation check constrains analysis of this explanation, but participants engaged in the mindfulness meditation just prior to headset application, so it also possible that any transient effects of the meditation faded during headset application procedures. Considering these factors and related findings about mindfulness meditation in prior VR research [6], we suggest further exploration of its potential to increase VL.

Beyond mindfulness meditation, there have long existed contemplative practices that more specifically target the cultivation of lucidity. The contemplative practice of illusory form yoga entails ongoing appraisal of what one perceives as being like a dream. This is actually intended to deepen conscious engagement with moment-by-moment experience, rather than lead to dissociation or escapism [16]. Additionally, practicing illusory form during waking is thought to support lucidity during dreaming, which may have a host of additional benefits. In the context of VR, we expected that illusory form practice would similarly support greater awareness of the illusory (virtual) aspects of current experience (i.e., VL). Accordingly, we found higher VL and lower fear, without difference in enjoyment level, among lucid dream trainees engaging in this practice. There was also marginal support that those engaging illusory form were more likely to step off the plank, and VL mediated this relation. These initial findings may be useful for guiding experimental research on illusory form yoga.

6 Limitations and Future Directions

As the first investigation of VL, this preliminary study involved the following limitations that can help guide future research. First, our combined experimental and cross-sectional approach does not allow for causal interpretation of illusory form yoga on observed differences in VL, SUDS, and behavior. Second, as noted regarding lack of effects of mindfulness meditation, further investigation of its potential to influence VL could be valuable, particularly using more robust (i.e., higher "dosage") mindfulness training in a meditation-naïve sample. Relatedly, although we assessed meditation experience in two ways, there is yet no standard approach to quantifying meditation experience, and research would benefit from a more objective or systematic approach. Third, although we relied on the Firth penalized likelihood method for logistic regression [13], the rarity of not stepping off the plank ($N = 8$), as well as our relatively small sample size, warrants caution in interpreting these findings. Fourth, our reliance on a measure adapted from lucid dreaming research afforded this initial investigation of VL, and its overall pattern of relations with relevant variables is promising. However, there is a need for more research on the validity and reliability of this or other measures of VL. Finally, future research will benefit from the inclusion of additional behavioral and/or physiological measures.

7 Conclusion

The potential of VR to create a sense of being present in virtual environments, despite conceptual understanding of their illusory nature, has long been viewed as a kind of paradox at the experiential center of VR [28][31]. This view has primarily driven research focused on one side of this seeming paradox of presence, namely the potential of VR to elicit responses as though the experience was *not* virtual. This study focused instead on a new construct pertaining to variation in conscious awareness that one's experience *is* virtual. Specifically, virtual lucidity (VL) entails conscious recognition of virtual aspects of current experience, including regulatory affordances directly supported by this recognition. We examined VL in the context of a virtual threat scenario that involved walking, and then being asked to step off, a wooden plank seemingly located high above a city.

Results revealed that VL predicted lower fear, more enjoyment, and greater likelihood of stepping off the plank. Further, a number of factors related to lucidity during dreams, including frequency of lucid dreaming, similarly predicted VL and lower fear. Lucid dream trainees on retreat, engaged in the contemplative practice of illusory form yoga, experienced more VL, lower fear, and marginally higher likelihood of stepping off the plank compared with nonretreatants. Finally, VL mediated all significant relations between predictors and outcomes, consistent with its potential to afford regulatory monitoring and control. Associations held controlling for either presence or fear of heights.

Overall, these results highlight how the seemingly paradoxical quality noted in presence research—of engaging deeply yet knowingly in illusory experience—may be linked to a naturally occurring mental state, namely lucid dreaming, for which there exist suitable methods of mental training. As detailed in examples earlier, VL and its link to lucidity in dreams may also inform the development and application of VR, such as in brain-computer interfaces that offer more control over, and realism of, virtual worlds as VL increases. In the context of advancements in VR and related technologies likely to promote increasingly more presence in and realism of virtual experience, findings from this initial investigation prompt a call for further targeted research on VL.

Acknowledgments

We thank Shambhala Mountain Center, Reality Garage, and Peter Grossenbacher, PhD, for their support of this project. We also thank Christina Luberto, PhD, for her helpful feedback on a manuscript draft. Finally, we thank the research assistants who helped with this project: Patrick Martin, Naomi Brodner, Justin Weiss, Dylan Leigh, Danielle LeVee, Alyssa Gursky, and Sierra Hofstatter.

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