# Presence, embodied interaction and motivation: distinct learning phenomena in an immersive virtual environment


Jack Ratcliffe
Queen Mary, University of London
London, United Kingdom
j.ratcliffe@qmul.ac.uk

Laurissa Tokarchuk
Queen Mary, University of London
London, United Kingdom
laurissa.tokarchuk@qmul.ac.uk



**Figure 1: Image of the immersive virtual environment showing player interaction markers and various interactable objects**


## ABSTRACT

The use of immersive virtual environments (IVEs) for educational purposes has increased in recent years, but the mechanisms through which they contribute to learning is still unclear. Popular explanations for the learning benefits brought by IVEs come from motivation, presence and embodied perspectives; either as individual benefits or through mediation effects on each other. This paper describes an experiment designed to interrogate these approaches, and provides evidence that embodied controls and presence encourage learning in immersive virtual environments, but for distinct, non-interacting reasons, which are also not explained by motivational benefits.




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## CCS CONCEPTS

• **Human-centered computing → Virtual reality**; **HCI theory, concepts and models**; **Gestural input**; • **Applied computing → Interactive learning environments**.

## KEYWORDS

interactive virtual environments, motivation, presence, embodiment, virtual reality, learning, language, gestural input

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## 1 INTRODUCTION

Virtual environments have the potential to significantly improve the efficacy of computer-based learning, due to unique affordances such as 3D spatial representations, multi-sensory and multi-modal channels for user interaction, and immersion of the user [34]. These aspects are enhanced in immersive virtual environments (IVEs), which provide embodied 3D spatial representations, add further and naturalistic interaction modalities and have been shown to increase immersion [52]. While these features are considered beneficial to learning outcomes, the underlying mechanics of why they contribute is still unclear. Contrasting views have attributed their impact to three main interactions: the relationship between IVE, motivation and learning [30]; between IVE, presence and learning [35]; and between IVE, embodiment and learning [25].

Of these viewpoints, the relationship between motivation and learning is the most developed. It is widely accepted that learner motivation has a positive impact on learning outcomes [8]. IVEs have been recorded as being motivating learning arenas, although it is still unclear whether this is due to the technology novelty effect [7] and therefore if the motivational benefits would continue to occur when IVEs are as ubiquitous as other forms of computer-aided learning.

Advocates of the IVE, presence and learning relationship believe that enhanced "presence" (the feeling of "being there" in a virtual environment [50]) improves learning outcomes. The reasons for the impact of presence on learning are debated: some believe that presence alone is a phenomena that directly effects learning [36], while others believe it is a useful way of measuring how a system contributes to a variety of established variables that benefit learning, such as motivation or engagement [43] [20].

A similar chicken-or-egg dichotomy exists regarding the benefits of embodied interaction within IVEs. Some research contextualises the impact of embodied interaction as a contributory factor of another cause of learning. For example, embodied interaction has been shown to be a contributor to presence [10], where presence positively effects learning [23]. It has also been shown as a contributor to motivation and engagement [26]. Embodied cognition [55] proponents, however, argue that its benefits stem primarily from enabling more of our bodies to interact with the learning process: it allows us to use our bodies to make meaning in an embodied way [25] [16]. A summary of the motivation, presence and embodiment relationships can be seen in Fig. 2.

While many IVE learning investigations monitor motivation, presence and embodiment, few have monitored these in the same experience or investigated how they relate to each other to promote learning (or if they interact at all). There is increasing demand for this kind of fundamental understanding of what factors influence learning in IVEs [13]. In this paper, we seek to understand the relationship between these three factors and learning, through a controlled experiment that varies embodiment modalities while monitoring presence, motivation and learning outcome. The experiment provides evidence that, in this investigation, presence and embodied controls have distinct impacts on learning outcome, separate from motivation and each other. It supports the embodied cognition approach to learning, which suggests there is something fundamentally embodied about how we learn, and that leveraging embodiment produces unique learning benefits within IVEs.

# 2 LITERATURE

## 2.1 Motivation and learning

Motivation literature is extensive, has been studied from multiple perspectives, and resulted in many theoretical frameworks. Broadly, motivation is considered the energisation and direction of behavior [40]. Strong links between motivation and learning have been found, with the phenomena considered the "key to persistence and to learning that lasts"[6], with many reviews showing evidence for a strong correlation between motivation and learning success [8] [17]. These links are also well-evidenced in instructional games [53] [37], with games primarily seen as a means to enhance intrinsic motivation [11]. A learner who is intrinsically motivated undertakes an activity "for its own sake, for the enjoyment it provides, the learning it permits, or the feelings of accomplishment it evokes" [22].

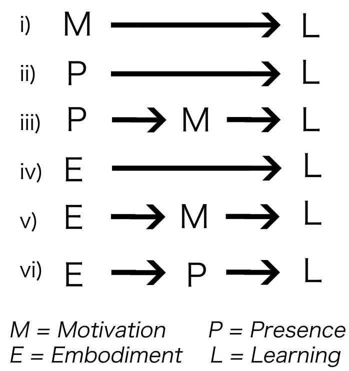



**Figure 2: Approaches to relationships between motivation, presence, embodiment and learning. Examples iii, v and vi depict mediated relationships.**

While the motivation and learning link is well-established, the methods for recording motivation are still evolving, especially in the instructional games space. A prominent model for understanding intrinsic motivation is Keller's ARCS model [19], which examines motivation as attention (holding the learners' interests and attention), relevance (show the usefulness of the content), confidence (help students understand their likelihood for success) and satisfaction (learners should be satisfied of what they achieved during the learning process).

A number of instructional game evaluations have built upon Keller's model, including the MEEGA+ game experience survey [39] used in this paper. The MEEGA+ records a motivation metric, but also treats motivation as a composite part of "player experience", arguing that it is difficult to distinguish the impact of game design factors, such as game immersion and system usability, from the metric of instructional game motivation (e.g. it is difficult to be motivated to learn in an instructional game when the head-mounted display technology makes you feel motion sick [41]).

## 2.2 Presence: unique benefits, or motivated by motivation?

It has been theorised that enhancing the feeling of presence in a learning system can benefit learning outcomes [38]. However, research into whether presence affects learning, and the mechanisms responsible for its impact, has thus far failed to prove conclusive.

Although it appears high levels of presence among learners are related to better learning outcomes [18], there are also studies that show the opposite: increased presence correlated with worse learning outcomes [31]. Presence has also been difficult to define and measure consistently, with presence levels in IVEs varying wildly [27].

Where a positive relationship between presence and learning has been found, there are often competing perspectives on why the learning occurred. Perhaps the most prolific explanation is that the learning benefits offered by increased presence are a result of a positive relationship between presence and motivation [30] [31] [43] [20]. In essence, more presence means greater motivation, which means better learning (iii on Fig. 2).

A contrasting view is that presence is a unique phenomenon that impacts learning directly, not through the proxy of motivation (ii on Fig. 2). One possible explanation for this is that the enhanced emotional involvement of feeling "present" in a situation [5] encourages better learning. This would explain why IVEs concerned with emotive subjects, such education around climate change, show both increased presence and learning [32]. The link between presence and strong emotional responses in users, such as empathy and anxiety, is well-established [45].

A more prosaic perspective, not investigated here, is that presence has no causal relationship with learning, and that there only appears to be one due to the affordances of the immersive hardware that enable both presence and learning [13]. For example, it is far more difficult for a learner to get distracted from learning when using a head-mounted display, as the screen is strapped to their face [13] which, coincidentally, also serves to increase their sense of presence.

## 2.3 Embodied controls and embodied cognition

Embodied controls, as they are used here, refer to input systems for digital experiences that require a conscious gesture from the user. This is also referred to as kinesthetic inputs or gesture-based inputs. There are many reports that demonstrate that embodied controls enable learning, and comparative studies have also shown that embodied controls have provided learning benefits over non-embodied alternatives [54] [9] [29] [42].

Advocates of adding embodied controls to learning IVEs are split on how to explain the reasons for its benefits. Part of this is due to the ancillary effects of embodiment: as with presence, most studies have found that adding embodiment increases motivation [21][51][12][24][47], and motivation is a key indicator of learning success. Therefore it is easy to consider the key benefit of embodiment as increased motivation (v on Fig. 2; similar discussions also occur outside of computer-based learning [1][28]).

While there is an acute relationship between embodied controls and motivation, there are two alternative theories: that embodied controls increase presence (vi on Fig. 2), which has an impact on learning [2]; or that embodied controls leverage aspects of embodied cognition, which leads to better learning outcomes [29] (iv on Fig. 2).

There is evidence of a relationship between embodied controls and presence [2][33][44], although there is contrasting research [46]. The embodied control-presence relationship is also considered weaker than the relationship between head-mounted displays and presence for cognitive learning [13].

The embodied cognition perspective suggests that presence is not relevant to the benefits offered by embodied controls. It posits that cognitive processes are rooted in the body's interactions with the world [56], and therefore by replicating more naturalistic interaction through embodied controls, we can enhance learning by synthesising a more natural learning process [29]. Literature shows benefits of leveraging embodiment in IVEs, but few (if any) have also controlled for motivation. Motivation is either not tracked [54], or the comparison typically falls between an IVE with embodied controls and a completely IVE-free alternative, such as rote memorisation from written lists or classroom learning. Other research has examined the impact of embodied controls, but not as part of an IVE [9].

It is clear, then, that to provide more insight into the causes of learning benefits in IVEs, we need to create an experiment that allows for a variation of embodied control type, and monitors presence, motivation and learning gain.

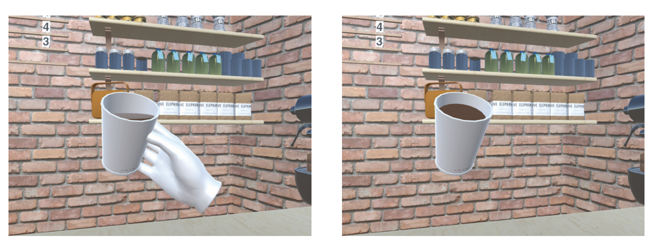
# 3 EXPERIMENT

We ran an experiment to understand the impact of embodiment controls on word memorisation in an IVE. We compared embodied controls with spoken interaction against a control (non-embodied controls with spoken interaction). We monitored co-variables considered related to learning in IVEs, including presence and motivation, and tracked learning outcome in order to explore the relationship between embodied controls, presence, motivation and learning outcome.

## 3.1 Hypotheses

Our hypotheses derive from the motivation, presence, embodiment and learning outcome relationships found in literature and displayed in Fig. 2. These are:

- h1. Motivation score correlates with learning gain
- h2. Presence score correlates with learning gain
- h3. The relationship between presence and learning gain is mediated by motivation
- h4. Embodiment score correlates with learning gain
- h5. The relationship between embodiment and learning gain is mediated by motivation
- h6. The relationship between embodiment and learning gain is mediated by presence



Embodied + spoken    Spoken only

**Figure 3: Environment interaction differences**

## 3.2 Procedure

Each participant was assigned to either an embodied controls and spoken production group, or a spoken production-only group. They were then presented with 10 interaction areas inside a virtual coffee shop setting. Each interaction area contained an object and a related action. When a participant reached an interaction area, a voice-over introduced the object and explained the possible action in both English and Japanese (i.e. "This is a drink. Drink in Japanese is nomimono. You can pour it. Pour in Japanese is sosogu").

Depending on their assigned group, the participant was then asked to either:

- Say the object and action words, and then complete an accompanying gesture by grabbing and moving the item using their embodied controls
- Say the object and action words, then watch the object complete a corresponding animation

Participants were introduced to each interaction area in sequence, then given 10 minutes to freely explore the environment and attempt to memorise the words.

Each participant only experienced one of the above conditions (between-subject design). If a correct embodied and spoken input (or for the control, spoken-only input) was recognised, that interaction would end and a participant may visit the other interaction areas. Failed recognition re-prompted users until they correctly performed the embodied and spoken input. Users could also leave an interaction area at any point.

## 3.3 Participants

Twenty-four uncompensated participants (15 male, 7 female) were asked to self-report their knowledge of the target language (Japanese) and were pre-tested for their knowledge of the words used in the experiment. Around 60% of participants were recruited from within Computer Science, with the remaining 40% from other disciplines and outside of the university. They aged in ranges 20 - 29 (8), 30 - 39 (12) and 40 - 59 (4). No participants demonstrated an extensive knowledge of the target learning words during the pre-test ($M$ = .13; $SD$ = .44) nor self-rated their ability as above "basic phrases". Most participants were fluent in more than one language, but we did not find a difference in learning outcome between mono-lingual and multi-lingual participants ($t(22) = -.84$, $p = .20$; mono-lingual: $M$ = 6.17, $SD$ = 3.18 ; multi-lingual: $M$ = 7.83, $SD$ = 4.25). Twenty-one participants were educated to post-graduate level or above. The majority of participants played digital games “rarely or never” (16 of 24), with only four playing them “daily”. The majority had also had little experience with IVEs, with 20 of 24 participants having “rarely or never” experienced virtual reality, and only two of 24 using it “weekly” or more regularly. A visual inspection suggested there was not enough variance in answers related to interest levels in Japanese, Japan, virtual reality and coffee shops to prove useful for further analysis.

## 3.4 Corpus

Participants were tested on their knowledge of 10 noun/verb pairs (20 words). Japanese gairaigo (import words) were specifically avoided to reduce the chance of participants' inferring a meaning.

The target words were chosen to be contextually relevant to the learning setting (i.e. a cafe), and to have high congruence between verb and noun (e.g. it is congruent to pour milk, but not pour cake). They were chosen in consultation with a Japanese language teacher, and, in English, are: move, put, stir, money, black tea, eat, wipe, bag, pay, pour, take, cake, door, napkin, cover, open, spoon, drink, lid, milk.

## 3.5 Environment

We created a 3D coffee shop environment in Unity to provide a situated context for memorising nouns and verbs related to a coffee shop. The environment was explorable via a head-mounted display and embodied controllers (the Oculus Rift S and Touch controllers). Navigation could be done by moving around the real space; by using the thumbsticks on the controllers; or a combination of both.

## 3.6 Evaluation

Participants' knowledge of the Japanese content was measured in three tests: one administered before their exposure to the environment (pre-test); one immediately after (post-test), and one seven days later (week-test). Participants performed the same test each time, listening to a Japanese word and typing the English (or another) language translation if they knew the meaning. The week-test was conducted via the internet in uncontrolled conditions. Each question was timed and we found no significant difference between time taken for immediate-test and week-test completion, suggesting that participants avoided looking-up answers or being distracted (in a way that could be measured by time) during the evaluation.

Participants were not given feedback when submitting answers. The maximum score was 20. Learning gain was measured as post-test score minus pre-test score. Only two participants knew any words beforehand, knowing one and two words. Because of this low result compared with the potential number of learning items, we felt it was not necessary to normalise the scales of these participants.

After using the system, participants were asked to complete a MEEGA+ educational games experience questionnaire [39] to provide insight on their motivation when using a computer learning system. MEEGA+ provides distinct values for user experience (9-items) and motivation (24-items). We examined the user experience metric for outliers to ensure that no participant had usability issues that may have harmed outcomes. We used the motivation score as our motivation metric. We choose MEEGA+ due to its theoretical basis as a tool for examining participant motivation with a system-as-learning tool, rather than the participant's motivation with the entire experimental experience, or the participant's motivation with the learning outcome (i.e. learning Japanese). We felt this would give us a clearer idea of the impact of the system on motivation.

Participants were also asked to self-report their level of presence while inside the environment on Slater's single-item, 6-point Likert scale [49]. The use of one-item presence surveys have been examined and been found to be well-understood, reliable and valid [4], while asking participants for their subjective evaluation of presence experienced is considered the most direct way of presence assessment [15].

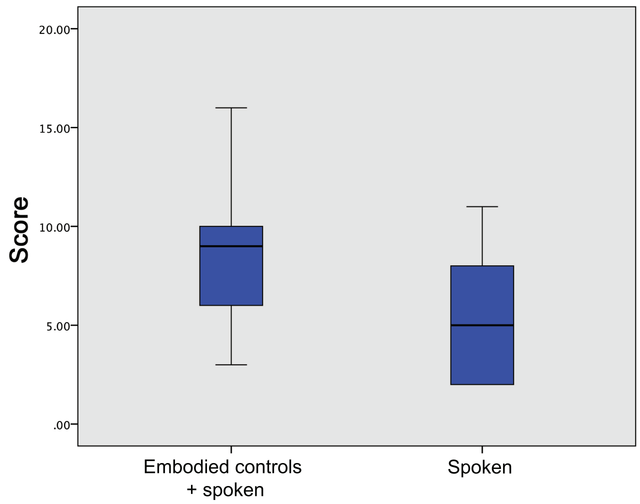



**Figure 4: Showing immediate learning gain difference in embodied and spoken vs. spoken groups**

## 3.7 Analysis

In order to test our first three hypotheses (h1, h2, h3), we tested for correlation between motivation and learning gain; between presence and learning gain; and between presence and motivation; using Pearson's r.

To test our fourth hypothesis (h4), we used a one-tailed independent t-test on the learning gain scores of the two interaction groups to understand if the use of embodied controls led to better learning gain.

For our fifth hypothesis and sixth (h5, h6) we used a correlation matrix followed by multiple linear regression to understand potential contributions of motivation, presence and embodied control to learning gain, and tested for mediation effects.

We also investigated if embodied controls had a significant impact on presence, using a Mann-Whitney U-test (as presence data was not normally distributed); and a second U-test to evaluate if embodied controls had a significant impact on motivation (as motivation data did not meet the requirement of homogeneity).

# 4 RESULTS

See Table 2 for a correlation coefficient matrix between immediate learning gains, motivation, presence and embodied control; and Table 3 for a table showing the coefficients between one-week learning gains and the other variables.

We noted one participant's learning gain results were quite high compared with others, but they were not considered a significant outlier according to Grubbs' test.

## 4.1 Motivation and learning gain

Our results for the relationship between motivation and immediate learning gain were non-significant and showed a weak positive correlation ($r(22) = .29$, $p = .082$). However, our results for motivation and one-week showed a significant weak positive correlation ($r(22) = .35$, $p = .049$). See Fig. 5.

## 4.2 Presence and learning gain

Presence results showed evidence of a significant and moderate positive correlation with immediate learning gain ($r(22) = .41$, $p = .04$), and a significant but weaker correlation for one-week learning gain ($r(22) = .35$, $p = .045$).

## 4.3 Presence, to motivation, to learning gain

We found a non-significant weak positive correlation ($r(22) = .19$, $p = .16$) between presence and motivation. The earlier non-significant, weak correlation between motivation and learning gain is also relevant.

## 4.4 Embodied controls and learning gain

There was a significant difference in immediate post-test scores for embodied control ($M = 8.79$, $SD = 4.09$) and non-embodied control ($M = 5.5$, $SD = 3.17$) conditions, showing a large effect size ($t = 2.03$, $p = .03$, $g = .88$). See Fig. 4.

However, for one-week later scores ($M = 5.7$, $SD = 3.97$; $M = 3.5$, $SD = 2.16$), there was no significant difference although a moderate

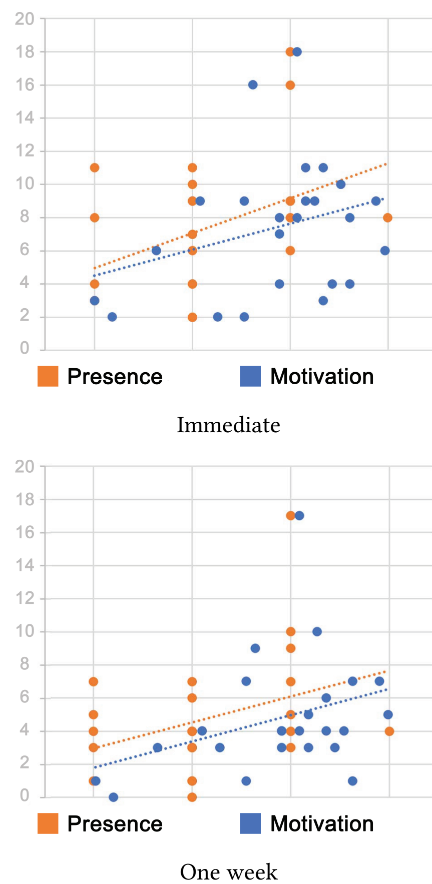



**Figure 5: Relationship between presence, motivation and test score. Y-axis depicts test score, X-axis depicts standardised presence and motivation results**

effect size was found ($t$ = 1.53, $p$ = .07, $g$ = 0.66). See Table 1 for learning gain results.

The results for embodied controls and non-embodied controls were both normally distributed and met requirements of homogeneity of variance.

## 4.5 Embodied controls, to motivation, to learning gain; and embodied controls, to presence, to learning gain

*4.5.1 Immediate learning gain.* A multiple linear regression showed that motivation, presence and embodied control predictors were not significant when all three were included in the model and explained 19% of the learning outcome variance ($R2$ = .192). Using backwards step-wise regression, we found that presence (*Beta* = .355, $t(21)$ = 1.89, $p$ < .05) and embodied control (*Beta* = .355, $t(21)$ = 1.78, $p$ < .05) explained a significant amount of the variance in immediate learning gain. For this analysis, embodied control was coded as "1", representing a consistent, high amount of hand embodiment, and non-embodied control was coded as "0", representing a consistent low amount of hand embodiment. Tests showed that multicollinearity was not a concern.

We used Baron and Kenny's mediation test [3] to understand the mediation effects of presence on embodied controls, and motivation on embodied controls. Embodied control was not found to have a significant relationship with presence ($t(22)$ = 0.84, $p$ = .21) nor motivation ($t(22)$ = 1.51, $p$ = .07). Therefore we found that while embodied control and presence impacted learning gain, we could not find a mediation effect of presence on embodiment. Motivation was not a significant regressor of learning outcome, therefore we could also not find a mediation effect of motivation on embodied control.

We also found no significant difference between the presence scores for embodied controls or non-embodied control conditions ($U$ = 57, $p$ = .23) in a Mann-Whitney U-test, which further evidences that the embodied control conditions had limited impact on reported presence. Similarly, we found no significant relationship between embodied control conditions and motivation ($U$ = 49, $p$ = .12).

*4.5.2 One-week learning gain.* We have evidence for relationships between presence and one-week learning gain, and motivation and one-week learning gain (see Fig. 5). Both showed weak significant correlations.

Multiple linear regression showed that motivation, presence and embodied control predictors were not significant when all three were included in the model and explained 12.4% of the learning outcome variance ($R2$ = .124). Using backwards step-wise regression, we found that only presence (*Beta* = .354, $t(22)$ = 1.77, $p$ < .05) explained a significant amount of the variance in the one-week learning gain.

As embodied controls was not found to be a significant regressor of learning gain, we found no evidence that presence or motivation mediated embodied control.

**Table 1: Learning gain from immediate and one-week tests**

| Type | Mean | SD | Min | Max |
|---|---|---|---|---|
| Embodied immediate | 8.79 | 4.09 | 3 | 18 |
| Non-embodied immediate | 5.5 | 3.17 | 2 | 11 |
| **All immediate** | **7.42** | **4.07** | **2** | **18** |
| Embodied week | 5.71 | 3.97 | 1 | 17 |
| Non-embodied week | 3.5 | 2.16 | 0 | 7 |
| **All week** | **4.79** | **3.51** | **0** | **17** |

# 5 DISCUSSION

## 5.1 Motivation and learning gain

Our results showed a mixed relationship between motivation and learning gain. Motivation did not significantly correlate with immediate learning gain, but was significant and showed a stronger (but still weak) correlation with one-week learning gain. This suggests that either motivation is only an impactful contributor to forming long-term memorisations, or that our process was not sufficient to correctly understand the relationship between motivation and immediate learning gain. This could be due to our choice of motivation survey, which focuses the motivation metric on the participants' experiences with the learning system itself, rather than wider motivation for the learning subject. A robust future exploration would likely include both the system-level motivation and a wider examination.

Another explanation could be that all participants were generally motivated to a similar level, with 22 out of 24 participants reporting positive motivation scores. This could be a potentially useful outcome for future studies concerned with investigating links between motivation and other variables inside IVEs, as it suggests there are limitations in analysing motivation scores in already highly-motivating experiences.

## 5.2 Presence and learning gain

The relationship between presence and learning outcome was shown to be significant and moderate for both immediate and one-week learning results, which does not reject h2. As the presence, motivation, learning paradigm was rejected, this result suggests that there is something implicit and important about presence itself that contributes to learning, and it is not simply a causal factor for motivation and its effects.

## 5.3 Presence, motivation, learning gain

The weak correlation and lack of a significant relationship between presence and motivation shows no evidence of presence enhancing motivation. As presence also has a significant correlation with learning gain, the combination of these two outcomes means that there is no evidence that motivation has a complete mediation effect on presence, rejecting h3.

## 5.4 Embodiment and learning gain

The relationship between embodied controls and immediate learning gain was shown to be significant, but not between embodied controls and one-week learning gain. This means h4 is accepted for

**Table 2: Correlation coefficient matrix. "Score" refers to immediate learning gain. † denotes moderate correlation, * denotes significance**

| | Score | Motivation | Presence | Embodi. |
|---|---|---|---|---|
| Score | 1 | | | |
| Motivation | 0.29 | 1 | | |
| Presence | 0.41†* | 0.19 | 1 | |
| Embodi. | 0.40†* | 0.31 | 0.18 | 1 |

**Table 3: Correlation coefficient of variables for one-week learning gains. * denotes significance**

| | One-week score |
|---|---|
| Motivation | 0.35* |
| Presence | 0.35* |
| Embodi. | 0.31 |

immediate learning gain but rejected for one-week learning gain. This result could suggest that embodied controls only provide immediate learning benefits and the benefits of these erode over time. Comparing one-week learning gain means between the two embodied control groups (embodied: 5.7 vs non-embodied: 3.5) shows that there is still a notable difference in performance in favour of the embodied controls group, even if this is not significant. Therefore it is also possible that because learning gain drops after one-week, and this reduces the gap between the results of the two groups, that our experiment's relatively small sample size was no longer sensitive enough to find a difference.

## 5.5 Mediating factors

Our results did not evidence of mediating factors on embodied controls, for either the immediate learning gain or the one-week learning gain. Combined with the result that embodied controls was found to have a significant relationship with learning gain, it is clear that there is no complete mediating effect present. It should be noted that there could still be partial mediating effects that are not evidenced in these results.

# 6 LIMITATIONS

There are some important limitations to this study. The first is with the data collection methods for presence and motivation. The method for measuring presence was not comprehensive, as, although the one-question presence survey used here is validated, and self-reporting is considered an effective method for rating presence, a more thorough approach would have additionally employed quantitative measurements, as there are concerns regarding whether questionnaires alone are suitable for establishing an accurate presence result [48].

Similarly, the metric for motivation used here is defined by the player's experience of the system, and not the learning subject matter. The metric is generated from the participants' feelings of confidence, challenge, satisfaction, fun, focus and self-perceived relevance to their learning goals, which only provides us with participant-system motivation. There are arguments that understanding intrinsic motivation for acquiring the target learning language, or for engaging in language learning or learning generally, may have given us a holistic understanding of participant motivation. The motivation scores reported by participants were also overwhelming positive, which limited the variance of the motivation factor.

The environment was also designed to maximise the physicality of the learning, with grabbable nouns and verbs as the target learning acquisitions. Therefore caution should be used in trying to extrapolate these results for more abstract language concepts, such as adjectives, and for other learning subjects. And even for language acquisition, a longitudinal study would be more advantageous over a single-session learning intervention [14].

# 7 CONCLUSION

Our results show that embodied controls and presence aid learning outcomes from this system, in ways unrelated to motivation or each other. Therefore enabling deeper levels of embodiment or presence could be a method for enhancing learning outcomes in IVEs.

Our results also support the idea that the contribution of embodied controls cannot be measured by looking at its impact on motivation or presence results alone, but should be considered as a unique contributory factor. This may depend, however, on how embodiment, or at least embodied controls, can be quantified for future comparative analysis. Finally, the results question how useful motivation works as a metric when recorded inside an already highly motivating experience.

Future work should more comprehensively test the conclusions presented here, ideally using more sensitive measures of presence, and extend the measures of motivation beyond system-level and towards a more subject-specific learning motivation, ideally in a longitudinal investigation.

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