Reactivation of Multimodal Representations and Perceptual Simulations for Meaningful Learning: A Comparison of Direct Embodiment, Surrogate Embodiment, and Imagined Embodiment

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Abstract: Embodiment has been found to enhance learning and motivation. It is proposed that during embodied experiences, learners reactivate multimodal representations of previously stored memories related to objects and events, and the mental perceptual simulations learners construct during embodiment enhance their learning and motivation. This paper presents the findings of a study that investigated the effects of different types of embodiment on the learning and motivation of adult learners. The study compared four groups, Direct Embodiment, Surrogate Embodiment, Imagined Embodiment, and No Embodiment (control). The findings suggest that learners learn better and have higher motivation when they engage in embodied learning than when they experience no embodiment, and that role-playing as avatars in virtual environments and role-playing physically both enhance learning and motivation more than imagining actions and reading. The findings suggest that role-play can make learning more meaningful.

Introduction

According to the embodiment premise, cognition depends not just on the mind but also on the body and people's experiences of their bodies in action (Gibbs, 2007; Robbins & Aydede, 2009). Embodiment or using bodily movements to enact knowledge and concepts can help people learn (Lindgren & Glenberg-Johnson, 2013). Theories of embodied cognition propose that embodiment improves memory and comprehension since it involves the construction of mental perceptual simulations and the reactivation of multimodal representations initially stored in memory during a learner's previous experience with an object or event (Barsalou, 2008a, 2008b). Furthermore, it is proposed that embodiment can lead to positive transfer of learning since learners learn to imagine during an embodied learning experience, and they are then able to use their imagination in new learning situations (Black, Segal, Vitale, & Fadjo, 2012). Empirical research on imagination and embodiment is further supported by neuroimaging data that indicate that the same brain regions are activated when we perform an action and imagine an action (Buccino, Binkofski, et al., 2001; Buccino, Riggio, et al., 2005; Hauk & Pulvermuller, 2004; Pulvermuller, 2008). Research findings suggest that embodiment can enhance memory, comprehension, transfer, and motivation (Barab, Dodge, Thomas, Jackson, & Tuzun, 2007; Bianchi-Berthouze, Kim, & Patel, 2007; Black, Khan, & Huang, 2014; Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004; Khan, 2012, 2013; Khan & Black, 2013, in press; Metcalf, Dede, Grotzer, & Kamarainen, 2009; Metcalf, Kamarainen, Grotzer, & Dede, 2011; Noice & Noice, 2001; Scott, Harris, & Rothe, 2001).

How can embodiment be used effectively to make learning a more meaningful experience for learners? I propose that embodied instruction and learning should specifically involve role-play activities in which learners can construct imaginary worlds (Black, 2007) through bodily movements. Role-play, whether it is through physical movements or virtual movements or imagined movements, can be expected to provide learners with the opportunity to engage with the learning material at a deeper level. Role-playing involves (a) an internal process in which the role-player uses certain conceptual constructs (i.e., the character she is playing, the game world, and the story), and (b) sharing this internal process with others through external expression (Lankoski & Järvelä, 2012). Embodiment via role-play provides immersive learning experiences in which the learner can put herself in another person's shoes (whether this is a fictional character or a character from history) to better understand learning material. The learner gets the opportunity to embody the character and enact a story through movement, gestures, dialogue, and the expression of emotions. This enables learners to relate more to the learning material and it can make learning more enjoyable by introducing an element of play into mundane learning material. Role-play also allows learners and instructors to collaborate during embodied learning experiences, in which instructors and peers can provide scaffolding to learners.

Theoretical Background

In spite of a growing body of evidence suggesting that embodiment enhances learning and motivation, embodied cognition is still developing towards a unified theory (Shapiro, 2011). Embodied cognition theories that explain cognition via mental simulations and reactivation of multimodal representations include *Perceptual Symbol Systems*, the *Indexical Hypothesis* and *Basic Systems Theory*. According to *Perceptual Symbol Systems* (Barsalou, 2008a, 2008b), whenever we experience some object or event, we store the memory of that object or event as multimodal representations. When we need to recall something about the object or event at a later time, we reactivate these multimodal representations as mental simulations of the object or event. *Basic Systems* also proposes that we simulate the multimodal components (including vision, audition, action, space, affect, and language) of a complex memory during retrieval (Barsalou, 2008a). The *Indexical Hypothesis* (Glenberg, 2008; Glenberg et al., 2004), which is related to *Perceptual Symbol Systems*, proposes that language comprehension involves (a) indexing words and phrases to objects in the environment or to perceptual symbols, (b) deriving affordances (Gibson, 1979) from the objects, and (c) combining the affordances according to syntax to produce a coherent simulation (Glenberg et al., 2004). The *Indexical Hypothesis* also corresponds with the *Ideomotor Theory* developed by Prinz about ideomotor mapping or forming learned associations between actions and their effects or between desired effects and actions (Glenberg, 2008). Boroditsky and Prinz (2008) have combined *Perceptual Symbol Systems* and *Indexical Hypothesis* to propose that two *Input Streams* are involved in cognition. According to them, people receive information from both perception and language and information is combined from these two input streams.

Black et al. (2012) have provided a theoretical framework that contributes to embodied cognition theory by specifically focusing on how embodiment can be used to deliver instruction. Their *Instructional Embodiment Framework* defines different types of embodiment that can be used for instruction and learning (see Figure 1). The framework divides embodied instruction into two main types of embodiment: Physical Embodiment and Imagined Embodiment. Physical Embodiment is further divided into Direct Embodiment (i.e., physically moving to perform actions during learning), Surrogate Embodiment (i.e., using a deputy to perform actions, such as controlling the actions of a virtual agent or avatar), and Augmented Embodiment (e.g., using touch devices and augmented reality). Imagined Embodiment is divided into Explicit (i.e., learners are explicitly instructed to imagine while learning) and Implicit (i.e., learners are not explicitly instructed to imagine while learning and imagining takes place at an implicit, latent level). According to Black (2007), imagination plays an important role in enhancing understanding and comprehension and constructing imaginary worlds during a learning activity can improve learners' memory and comprehension.

The *Instructional Embodiment Framework* proposes that embodied instruction is more effective as an instructional strategy than traditional non-embodied instruction since embodiment enables learners to construct mental perceptual simulations. Since mental perceptual simulations involve more than one modality, they can enable us to ascribe a deeper meaning to our experience making learning more meaningful. Based on this framework, a number of research studies suggest that learners learn better when instruction includes embodied learning experiences, and that embodied learning is further enhanced when there is a higher level of embodiment than when there is a lower level of embodiment or no embodiment (Black et al., 2012; Khan, 2012; Khan & Black, 2013, in press; Lu, Kang, Huang, & Black, 2011).

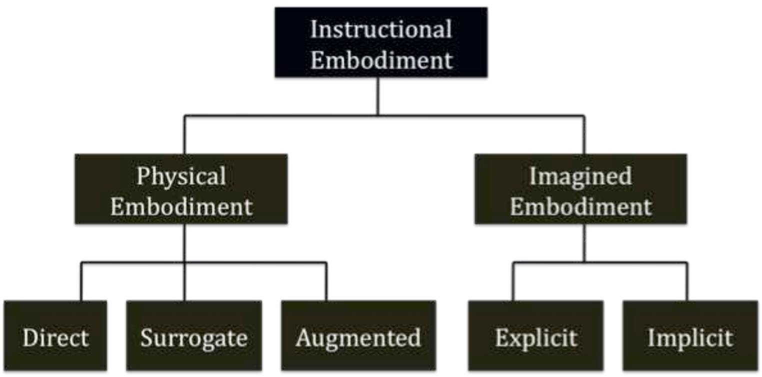

Figure 1. Instructional Embodiment Framework (Black et al., 2012).

The study presented in this paper investigated three different types of embodiment identified by the *Instructional Embodiment Framework* (i.e., Direct Embodiment, Surrogate Embodiment, and Explicit Imagined Embodiment), and compared these three types of embodiment with a no embodiment control condition. It may be noted that the group Imagined Embodiment in this study refers to Explicit Imagined Embodiment. Based on embodied cognition theory and previous research, I hypothesized that both physical and imagined embodiment would enhance learning and motivation more than no embodiment. Since physical embodiment can provide learners with more opportunities to construct multimodal mental perceptual simulations than imagined embodiment, I also hypothesized that physical embodiment would enhance learning and motivation more than imagined embodiment. I was also interested in finding out how surrogate embodiment (in which the learner sits in front of a computer and uses an avatar in a virtual environment to perform actions) would compare with direct embodiment (in which a learner physically moves and performs actions). Li, Kang, Lu, Han, & Black

(2009) investigated the effects of surrogate embodiment and direct embodiment as teaching and learning methods on students' understanding of abstract programming concepts. They found that children who learned in a direct embodiment condition (in which they acted like robots) showed higher gains in terms of comprehension and engagement as compared to children in a surrogate embodiment condition (in which they controlled the movements of a teacher who acted as a robot). Based on these findings, I expected learners engaged in direct embodiment to score higher on learning and motivation measures than learners engaged in surrogate embodiment.

Method

Participants

Eighty-four (N = 84) adult graduate students from a university in the United States participated in the study for course credit. Participants' age ranged from 21 to 50 years. A large majority (90%) of the participants were 21-30 years old, 50% were 21-25 years old, and 25% were 26-30 years old. There were 60 females and 24 males. The participants were from diverse cultural backgrounds. Participants identified themselves as Asian (42%), Caucasian (39%), African American (6%), Hispanic (5%), South Asian (4%) and Other (4%). All participants were proficient in English.

Design

The study employed a between-subjects posttest-only control group design. Four groups were investigated: (a) Direct Embodiment (DE), (b) Surrogate Embodiment (SE), (c) Imagined Embodiment (IE), and (d) a No Embodiment (NE) control. The dependent variables were memory retrieval, comprehension, near transfer, far transfer, and motivation.

Materials

The materials for the main learning task for all four groups included: (a) Novel historical text from the Indian subcontinent printed on paper about *Humayun*, India's Mughal Emperor, (b) illustrations and pictures of the main characters in the text, (c) Apple computers for the Surrogate Embodiment group, and (d) a blank A-4 size paper and pencil for the Imagined Embodiment group. Measurement materials included: (a) A memory retrieval paper and pencil test with twenty multiple-choice and open-ended questions that tested immediate recall of facts, (b) a comprehension paper and pencil test with ten open-ended questions that required participants to make inferences and think beyond the text, (c) a near transfer test, which was a history comprehension test, containing text from Indian history about the Queen of Jhansi that included elements common with the original text given during the main learning task followed by seven open-ended comprehension questions, (d) a far transfer test, which was a literature comprehension test, containing text from *Birbal*'s stories from Indian literature that included elements common with the original text given during the main learning task followed by seven open-ended comprehension questions, and (e) five motivation items on a questionnaire, which measured participants' enjoyment, confidence in their learning, increased interest in history, general interest and overall motivation. Participants responded to the motivation items on a five-point likert scale that ranged from strongly agree to strongly disagree. The maximum score for memory retrieval was 30, the maximum score for comprehension was 20, the maximum score for the near transfer test was 25, the maximum score for the far transfer test was 25, and the maximum score for motivation was 25.

Procedure

After the informed consent process, participants were randomly assigned to the four groups without knowing what condition they were in. All participants were given the same printed text, which they read silently one time, and they viewed pictures of the main characters in the text (these were illustrations and pictures of avatars). Next, participants were given the main learning task. The total time allocated to complete the task was 15 minutes. Participants in the Surrogate Embodiment group were given a brief tutorial and practice session before beginning the main learning task to familiarize them with their avatars and the features they were to use in a multi-user virtual environment. All participants were instructed to reread the text during the learning task.

For the learning task, participants in the Direct Embodiment group were instructed to physically play the role of the main character in the text (see Figure 2). All participants in the group interacted with and role-played with the experimenter, who played the role of another important character in the text. Participants in the Surrogate Embodiment group were instructed to play the role of the main character through an avatar (or virtual agent) and engage in virtual role-play in a multi-user environment (see Figure 3). Participants used virtual gestures and movements during the role-play. A confederate in a remote location controlled an avatar that represented the other character used in the role-play. The experimenter used the same script and the same characters in both role-plays. Based on the script, participants were free to create their own dialogue during the role-play. The Imagined Embodiment group was instructed to reread the text imagining the characters and the actions in the text. The No Embodiment (control) was not given any instructions other than to reread the text silently to control for time.

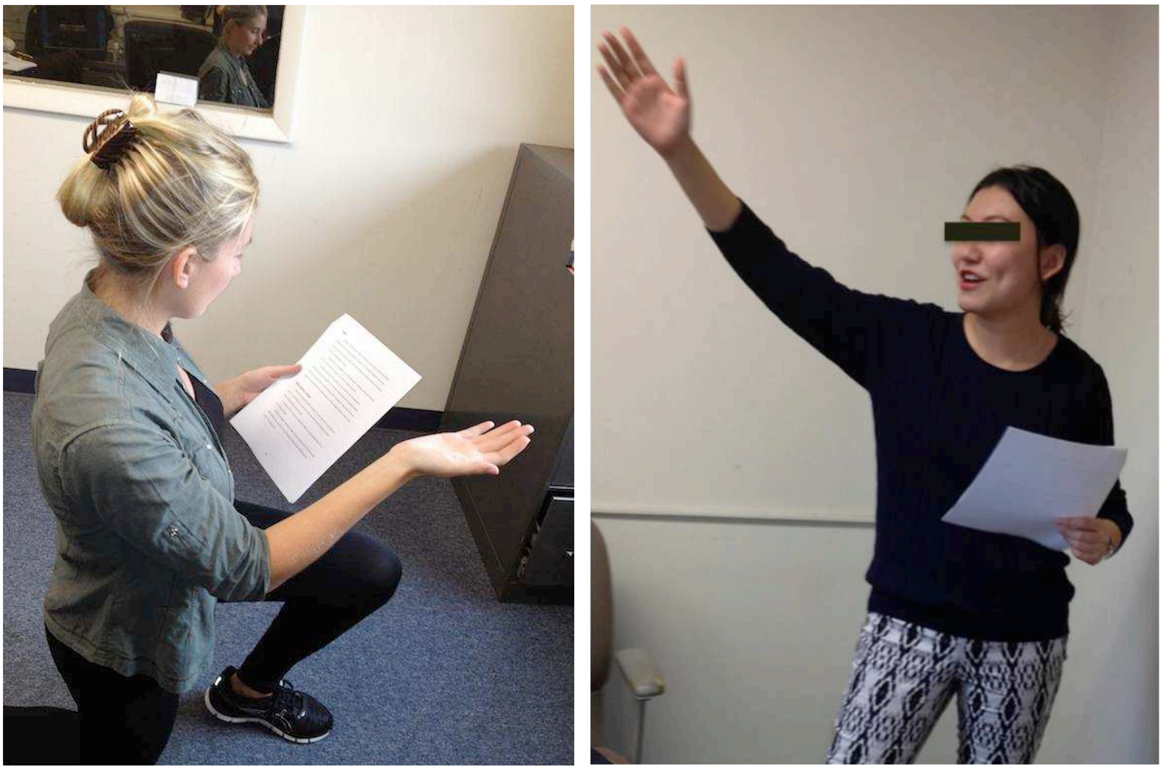

Figure 2. Physical Role-Play During Direct Embodiment.

Figure 3. Avatar Role-Play During Surrogate Embodiment.

After the learning task, all participants were given the memory retrieval test, comprehension test, near transfer test, and far transfer test. Participants were given a maximum of 15 minutes to complete each test. To create a delay between immediate recall and the transfer tests, a distraction task was used before the near transfer test in which the experimenter had a brief conversation with the participants. The experimenter followed the same script for all distraction conversations. After the far transfer test, all participants were asked to complete a questionnaire containing motivation items. The questionnaire also contained questions about participants' backgrounds, their attitudes and opinions about technology and history, and manipulation checks. All items other than the background questions required participants to select responses on a five-point likert scale that ranged from strongly agree to strongly disagree. The questionnaire was followed by a feedback session in which participants were asked questions to gain an insight into how they learned. All participants were debriefed at the end.

Results

Multivariate tests results were found to be statistically significant at the .05 alpha level, Wilks' $\Lambda = .252$, $F(5, 76) = 9.089$, $p < .001$, $\eta 2 = .369$. Groups were found to differ significantly on: (a) memory retrieval, $F(3, 80) = 21.543$, $p < .001$, $\eta 2 = .447$; (b) comprehension, $F(3, 80) = 17.267$, $p < .001$, $\eta 2 = .393$; (c) near transfer, $F(3, 80) = 36.497$, $p < .001$, $\eta 2 = .578$; (d) far transfer, $F(3, 80) = 40.167$, $p < .001$, $\eta 2 = .601$; and (e) motivation, $F(3, 80) = 10.287$, $p < .001$, $\eta 2 = .278$.

Table 1: Mean scores and standard deviations for all dependent variables.

	Direct Embodiment Mean (*SD*)	Surrogate Embodiment Mean (*SD*)	Imagined Embodiment Mean (*SD*)	No Embodiment Mean (*SD*)
Memory Retrieval	23.95 (2.31)	22.38 (2.91)	18.81 (2.77)	18.12 (3.03)
Comprehension	16.09 (2.45)	16.71 (1.65)	14.09 (2.93)	11.67 (2.82)
Near Transfer	16.86 (2.85)	15.28 (2.74)	10.52 (2.94)	9.14 (2.69)
Far Transfer	15.33 (3.15)	12.86 (2.97)	8.38 (2.11)	7.57 (2.29)
Motivation	22.14 (3.21)	20.76 (2.99)	19.24 (2.07)	17.52 (2.94)

Post-hoc Tukey HSD tests revealed that overall Direct Embodiment and Surrogate Embodiment groups performed better than Imagined Embodiment and No Embodiment groups. Direct Embodiment and Surrogate Embodiment did not differ significantly from each other on memory, comprehension, near transfer, and motivation, $p > .05$, but they did differ significantly on far transfer. Direct Embodiment scored significantly higher on far transfer than Surrogate Embodiment, $p = .018$. See Table 1 and Figure 4.

Both Direct Embodiment and Surrogate Embodiment scored significantly higher than Imagined Embodiment and No Embodiment on memory retrieval, near transfer, and far transfer, $p < .001$. Direct Embodiment scored significantly higher than both Imagined Embodiment ($p = .007$) and No Embodiment ($p < .001$) also on motivation. Surrogate Embodiment scored significantly higher than No Embodiment ($p = .002$) on motivation but it did not score significantly higher than Imagined Embodiment on motivation, $p > .05$. Surrogate Embodiment scored significantly higher than both Imagined Embodiment ($p = .006$) and No Embodiment ($p < .001$) on comprehension. Although Direct Embodiment scored significantly higher than No Embodiment ($p < .001$) on comprehension, it did not score significantly higher than Imagined Embodiment on comprehension, $p > .05$. This suggests that although Direct Embodiment and Surrogate Embodiment did not differ significantly on comprehension and motivation, Direct Embodiment enhanced motivation more than Imagined Embodiment while Surrogate Embodiment did not enhance motivation more than Imagined Embodiment. In contrast, Direct Embodiment did not significantly improve comprehension more than Imagined Embodiment while Surrogate Embodiment was found to improve comprehension more than Imagined Embodiment. See Table 1 and Figure 4.

Another interesting finding is that participants in the Imagined Embodiment group scored significantly higher than participants in the No Embodiment group on comprehension ($p = .013$), but the two groups did not differ significantly on any other dependent variable, $p > .05$. See Table 1 and Figure 4.

No statistically significant relationship was found between participants' gender, age, ethnicity, cultural background, and attitudes towards technology and history and the dependent variables.

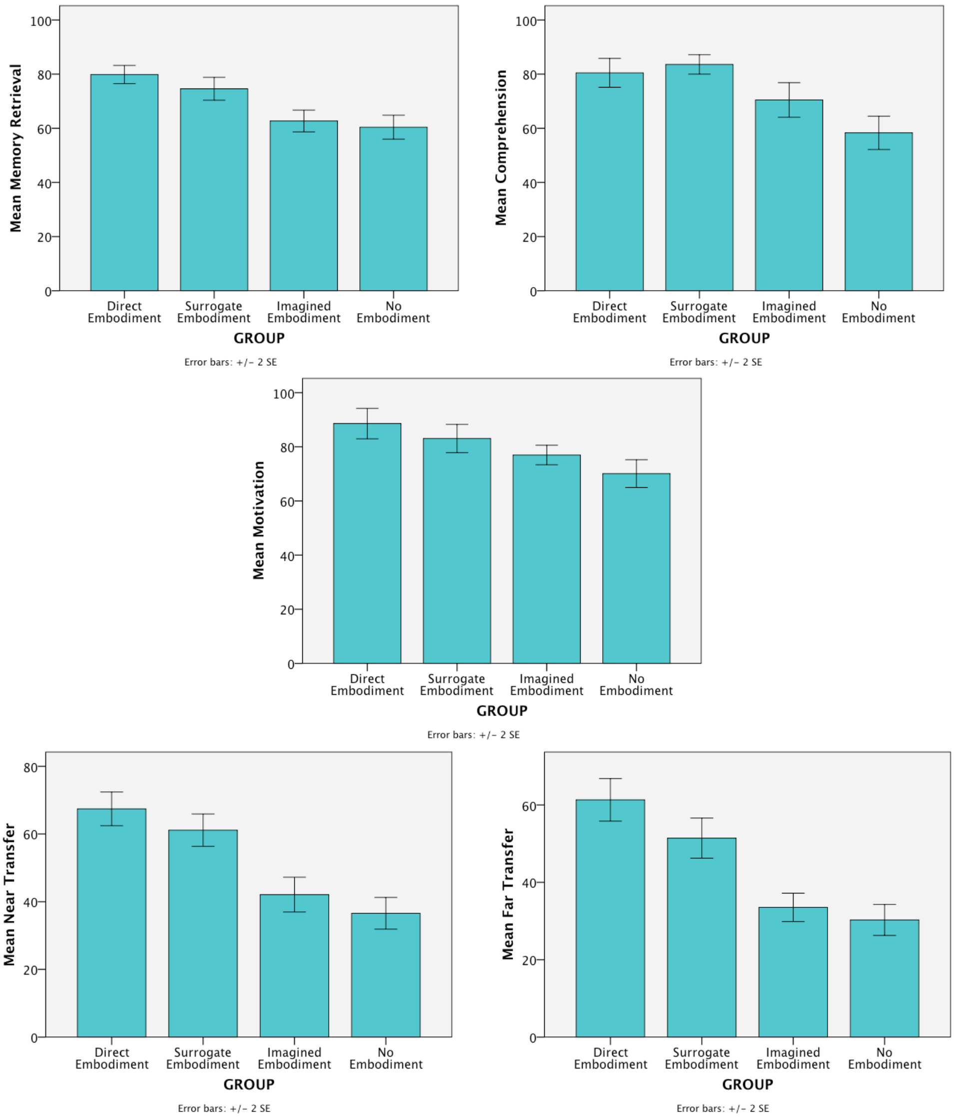

Figure 4. Mean Percentages for Memory Retrieval, Comprehension, Near Transfer, Far Transfer, and Motivation for All Groups.

Discussion

The results suggest that embodiment enhances learning and motivation and that constructing imaginary worlds improves comprehension. Our first hypothesis was that all three types of embodiment would enhance learning and motivation more than no embodiment. I found that participants who experienced both types of Physical Embodiment (i.e., Direct and Surrogate) scored higher than No Embodiment on all dependent variables. This supports previous research on embodied learning and instruction. I also found that similar to Direct Embodiment and Surrogate Embodiment, Imagined Embodiment enhanced comprehension more than No Embodiment. This finding supports research by Glenberg et al. (2004) who found that imagined manipulation enhances comprehension more than a no-manipulation read reread control condition.

Although I also hypothesized that Imagined Embodiment would score higher than No Embodiment on all dependent variables, I found that Imagined Embodiment did not enhance memory, near transfer, far transfer and motivation more than No Embodiment. This does not support previous research findings that suggest that imagining actions enhances memory and motivation more than no embodiment. For example, Glenberg et al. (2004) found that imagined manipulation enhanced memory and transfer more than a control condition. One reason for Glenberg et al.'s (2004) significant results could be that their participants were children who were given a relatively simple task. In our study, adult participants were given a completely novel text about the history of a country they were not very familiar with. The lack of a significant difference between Imagined Embodiment and No Embodiment scores could be attributed to the level of difficulty and the novelty of the text. Another possibility, one might argue, is that although the No Embodiment group was not explicitly instructed to imagine actions, participants in this group were engaged in implicit imagination. Since Black et al.'s framework especially considers Implicit Imagined Embodiment, I included manipulation checks that gathered information about whether or not participants in the No Embodiment group imagined actions while reading. Although participants reported that they did not imagine actions while reading, we must acknowledge that these were self-report measures.

I also hypothesized that Physical Embodiment (i.e., Direct and Surrogate) would enhance learning and motivation more than Imagined Embodiment. I found that participants in the Direct Embodiment group scored higher than participants in the Imagined Embodiment group on all dependent variables except for comprehension. Participants in the Surrogate Embodiment group scored higher than participants in the Imagined Embodiment group on all dependent variables except for motivation. The lack of significant gains in comprehension for Direct Embodiment compared with Imagined Embodiment could be attributed to attention. It may be assumed that since participants had to act physically and move around physically, this distracted them. On the other hand, one might argue that since Direct Embodiment and Surrogate Embodiment comprehension scores did not differ significantly from each other, attention might not be the issue. In that case, it seems more plausible that imagination plays a significant role in helping people understand text and our results indicate that imagining actions improves comprehension as much as physically performing actions. This also supports previous neuroimaging and empirical findings.

Direct Embodiment and Surrogate Embodiment groups did not differ significantly on memory, comprehension, near transfer and motivation, which suggests that virtual role-play was just as effective as physical role-play. Participants in both groups reported that they were able to imagine themselves as the main character during role-play and that helped them relate to the reading. Their feedback suggests that physical and virtual role-play made learning equally meaningful for them. These results do not support Li et al.'s (2009) findings that Direct Embodiment enhances comprehension more than Surrogate Embodiment. However, we must keep in mind that Li et al. investigated a different domain.

One interesting finding is that Direct Embodiment far transfer scores were significantly higher than Surrogate Embodiment far transfer scores. This suggests that physical role-play might have an advantage over virtual role-play with regards to far transfer. The question is why did participants in the Direct Embodiment group score significantly higher on far transfer than participants in the Surrogate Embodiment group when the two groups did not differ significantly on any other dependent variable? Direct Embodiment possibly involved the reactivation of more multimodal representations during simulation, and this might have contributed to the far transfer. Feedback from participants also revealed that most participants in the Direct Embodiment group were able to imagine themselves as the main character in the text provided in the far transfer test. They also reported enjoying this text more than participants in the Surrogate Embodiment group because they were able to imagine the story and imagine themselves as the main character. In this sense they seemed to be transferring the imaginary worlds construction from the main learning task to the far transfer test.

Conclusion and Implications

The findings suggest that embodied instruction via role-play can make learning more meaningful and it can significantly enhance learning, transfer, and motivation more than no embodiment. The findings also suggest that virtual role-play via avatars can be as effective as physical role-play in enhancing memory, comprehension, near transfer, and motivation. This has implications for teaching and learning. Physical role-play might not be feasible in classrooms due to time constraints. Physical role-play is also not possible in distance learning. The study, therefore, provides evidence for using surrogate embodiment via avatar role-play for teaching and learning. The findings also support theory and research on the role of imagination in learning. This suggests that embodiment can enable learners to approach learning in a manner that is enjoyable and relevant to them, which makes learning more meaningful.

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