# Chapter 2
# Implicit Learning Through Embodiment in Immersive Virtual Reality

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**Abstract** Virtual reality (VR) typically results in the illusion of presence. The participant in a VR scenario typically has the illusion of being in the virtual place, and under the right conditions the further illusion that events that are occurring there are really occurring. We review how these properties are useful for the application of VR in education. We present a further illusion that can be triggered in VR referred to as body ownership. This can occur when the participant sees a life-sized virtual body substituting her or his own, from first person perspective. This virtual body can be programmed to move synchronously with the participant's real body movements, thus leading to the perceptual illusion that the virtual body is her or his actual body. We survey various experiments that show that the form of the virtual body can result in implicit changes in attitudes, perception and cognition, and changes in behavior. We compare this with the process of implicit learning and conclude that virtual body ownership and its consequences may be used as a form of implicit learning. We conclude by suggesting how the study of the relationship between body ownership and implicit learning might be taken forward.

**Keywords** Virtual reality · Education · Implicit learning · Embodiment
Body ownership

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## 2.1 Introduction

In this article we consider how Immersive Virtual Reality may be useful for implicit learning, that is acquiring knowledge and skills without conscious effort, or without explicitly having to learn specific information. First, we briefly recap what virtual reality is (see also Chap. 1) and some essential concepts, then we review virtual reality in education and implicit learning, and go on to provide some examples of how it has been exploited to bring about changes in people. Note that for the purpose of this article we extend the notion of implicit learning to mean accomplishing changes to the self that were not explicitly programmed, including changes in attitudes, behaviors and cognition.

### *2.1.1 Immersive Virtual Reality*

Some background and history of Virtual Reality (VR) is discussed in Chap. 1 of this book, and further information and discussion of a range of applications is presented in (Slater & Sanchez-Vives, 2016). VR incorporates participants bodily into a virtual computer-generated world. A critical aspect is that as the participant turns or moves his or her head the computer updates the images displayed at a very high frame rate, ideally at least at 60 Hz. The participants therefore become immersed in a completely surrounding virtual environment that they see when turning in any direction with movement and motion parallax, and they perceive this (ideally) in a wide field-of-view display. (The same can be done with spatialized sound.) A way to grasp the difference between VR and other media comes from noting that in VR we can go into a virtual movie theatre and watch a movie. We can enter a virtual living room and watch a virtual TV. We can sit by a virtual computer and play a computer game—all while in virtual reality. In fact in VR we can even simulate the process of entering into a VR and thus enter realities within realities (Slater, 2009). There is no other technology that has ever enabled this.

### *2.1.2 Presence—Place Illusion and Plausibility*

The fundamental experience that VR delivers is referred to as ‘presence’. This is the perceptual illusion of being in the place rendered by the VR system. Presence in virtual environments was first elucidated in a set of papers in the early 1990s and there followed many years of further research into this concept reviewed in (Sanchez-Vives & Slater, 2005). Presence was deconstructed into two independent concepts in (Slater, 2009), referred to as *Place Illusion* (PI) and *Plausibility Illusion* (Psi). PI refers to the original idea of the illusion of being in the virtual place. It was argued that a necessary condition for this illusion is that the virtual reality is perceived through natural sensorimotor contingencies, a theory referred to as the active vision paradigm (O'Regan & Noë, 2001). This argues that we perceive through using our whole body, via a set of implicit rules involving head turning, leaning, reaching, looking around, bending an ear towards, and so on. The illusion of 'being there' can be generated to the extent that the VR system affords perception through natural sensorimotor contingencies. The argument is that if we perceive using the same methods in an environment as we normally perceive, then we must be in that environment, this being the simplest hypothesis for the brain to adopt.

Place illusion is the first effect of viewing a scene with a VR display. However, the Plausibility Illusion (Psi) is the illusion that the events experienced in VR are really happening (even though the participant knows that they are not). Psi requires that the virtual environment respond to actions of the participant, generates spontaneous actions towards the participant, and is ecologically valid when the environment is meant to depict real-life events. For example, when the environment includes virtual human characters, they should acknowledge the presence of the participant (e.g., by gaze) and respond to the participant's actions (e.g., by maintaining appropriate interpersonal distances).

When both PI and Psi operate then participants are likely to behave realistically in the VR. This has far reaching consequences. For example, VR has been used extensively for psychological therapy for 25 years. This is only possible because patients exhibit sufficient affect in VR as to enable the clinicians to engage in the therapeutic process.

### *2.1.3 Embodiment and Body Ownership*

A participant in a VR wearing a HMD looking in any direction would always see only the virtual world. What happens when the participant looks down towards his or her own body? If it has been so programmed then they would see a virtual body substituting their own. This virtual body would be life sized, approximately occupy the same space as where the person feels their real body to be, in other words be coincident in space with the real body. The body would be seen from first person perspective, i.e., from the eyes of the virtual body providing the centers of projection from which the participant sees the virtual world.

Seeing the virtual body from first person perspective is already a cue to the brain that it is the person's actual body, thus providing an illusion towards this effect. The illusion is enhanced if further multisensory feedback is applied. This follows from the fundamental finding reported in the rubber hand illusion. Here a person seated by a table has their real (say right) hand resting on the table but hidden behind a screen, and a right-handed rubber arm placed in an anatomically plausible position on the table in front of them, as if it were their real arm. Typically the hidden real arm and the rubber one are approximately parallel. The experimenter touches both the rubber hand and the hidden real hand synchronously so that the person sees the touches on the rubber hand but feels them on their real hand (Botvinick & Cohen, 1998). After a few seconds of such stimulation proprioception shifts to the rubber hand, so that although the person knows for sure that it is not their real hand, it feels as though it is. When the seen and felt touch are asynchronous then the illusion typically does not occur. Petkova and Ehrsson (2008) applied a similar technique to the whole body, to produce a full body ownership illusion. In this case a stereo camera was mounted on the head of a manikin pointing down towards its body, and the video streamed to a person wearing a stereo HMD. Provided that the person was looking down towards their real body, it would seem to them that their real body had been substituted by the manikin body. The experimenter synchronously tapped the abdomen of the manikin body (which would be seen through the HMD by the participant) and the abdomen of the person. Thus the person would see the manikin body being touched while feeling this on their real body, and integrate the two percepts into one overall illusion that the manikin body was their body. As with the RHI when the manikin body was threatened with a knife the participants exhibited an increase in physiological arousal concomitant with the attack. A synchronous tapping did not lead to these illusions.

It was demonstrated in (Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2008) that an equivalent to the RHI could be achieved in VR, where the person saw a virtual arm protruding from their shoulder, that was seen to be tapped by a virtual ball, that was in fact controlled by a tracked wand touching their corresponding real hand. Slater, Spanlang, Sanchez-Vives, and Blanke (2010) showed that a body ownership illusion could be attained over a virtual body, and that the dominant factor was seeing the body from first person perspective, although visuotactile synchrony also contributed.

Transformed body ownership was first tried in the very early days of VR in the late 1980s, although not as scientific research and therefore not published at the time. Lanier (2006) later reported that at VPL, the company he led, in the late 1980s and early 1990s they experimented with embodying people as virtual lobsters, and used unusual combinations of human muscle movements as a means by which people could move their lobster limbs. He termed this ‘Homuncular Flexibility’, meaning that humans can quickly adapt to new bodies and new modes of bodily control.

For the sake of terminology we refer to *embodiment* as the process by which the person’s body is substituted by a virtual one—using the head-tracked stereo head-mounted display, motion capture to track the person’s real movements and map these to movements of the virtual body, or tactile stimulation on the person’s body synchronous with virtual objects seen to touch the virtual body. Hence embodiment refers to the actual setup, whereas ‘body ownership’ refers to the perceptual illusion that the virtual body is the person’s own body (even though of course they know that this is not the case). Later we will be discussing the consequences of such virtual body ownership for implicit changes.

## 2.2 Learning

### *2.2.1 Intentional Learning*

As we have seen earlier VR has been developed, used, and studied for the past 25 years and there have been many applications in education. For recent reviews see (Freina & Ott, 2015). There are at least five reasons why VR may contribute to education: (i) Transforming the abstract to the concrete; (ii) Doing rather than only observing; (iii) The infeasible or impossible becomes practical; (iv) explore manipulations of reality; (v) go beyond reality to positive advantage. We consider each in turn. This section is based on (Slater & Sanchez-Vives, 2016).

#### 2.2.1.1 Transforming the Abstract to the Concrete

VR can transform abstractions into concrete perceptions and experiences. Hwang and Hu (2013) used VR and showing that it is advantageous compared to standard paper and pencil techniques in the learning of mathematics. Learning concepts about vector algebra and spatial abilities was described by Kaufmann, Schmalstieg, and Wagner (2000) using an HMD based augmented reality system. Roussou (2009) used a ‘virtual playground’ for the teaching of mathematics by 50 eight to twelve year olds, where children watched a virtual robot illustrating concepts leading to enhanced enjoyment, better conceptual understanding, and reflection.

#### 2.2.1.2 Doing Rather Than Observing

In general VR supports ‘doing’ rather than only observing. This is very important for example in neurosurgery training—e.g. (Müns, Meixensberger, & Lindner, 2014)—or any kind of ‘hands on training’, especially that is too problematic or dangerous to rehearse in reality.

#### 2.2.1.3 Doing the Infeasible or Practically Impossible

VR can be used to carry out activities that may be infeasible in reality. A good example here is learning geography, geology or archeology, where students would typically be unable to visit real places, but could instead visit them virtually. This idea of virtual field trips—e.g. (Lin et al., 2013)—has become popular and certainly feasible inexpensively with today’s relatively low cost hardware.

#### 2.2.1.4 Manipulating Reality

Einstein's famous thought experiment about riding on a light beam can become a concrete experience in VR. How would the world be if gravity were changed by a fraction? How would it be like to play football in such a world? The theories of relativity can be modeled and experienced in VR. Such ideas were propounded and implemented by Dede, Salzman, Loftin, and Ash (1997). These ideas are worth following up, since manipulating the parameters of reality is, course, not possible in reality, but in VR this is possible.

#### 2.2.1.5 Beyond Reality

VR is often thought of as a way to simulate and reproduce reality—for example, visit ancient archaeological sites such as Qumran as part of a history lesson (Cargill, 2008), or manipulate parameters of reality as discussed in the previous section. However, it is possible also to go quite beyond what is possible in reality in unexpected and radical ways. For example, Bailenson et al. (2008b) showed how teaching can be transformed where every student in a shared VR perceives that she or he is the center of attention of the teacher through placement in the classroom and through eye gaze feedback.

Generally with regard to VR and learning Fowler (2015) points out that too much emphasis has been placed on the technical affordances of VR (such as providing an immersion in a 3D space) and not enough on the pedagogical aspects of using VR. In particular VR applications must address (i) how the VR experience advances explanation; (ii) deepening understanding, for example, through exploration; (iii) taking account of the wider social context involved in learning. Any system that uses VR cannot escape demonstrating how these three required properties are satisfied. In the next section we consider, however, an entirely different approach that, it could be argued, obviates the need for such classifications, since the aim is learning, but not explicit learning. Moreover, all of the above examples rely essentially on the presence inducing aspects of VR: they transform learners to another world, and make use of the properties and affordances of that world for some type of learning. Instead we consider a more radical approach that while still necessitating presence also relies on body ownership.

### 2.2.2 *Implicit Learning*

Implicit learning is the process whereby individuals learn complex information unconsciously and gain abstract knowledge through this process (Reber, 1989). It has been applied, for example, to the learning of artificial grammars (Reber, 1967) where subjects are exposed to grammatically correct sentences over a set of symbols and asked to reproduce them while receiving feedback about which were correct or incorrect, without reasons why. There is no explicit learning of rules, and yet subjects are able to pick up the grammar after several such exposures. In particular subjects are able to correctly infer information about novel stimuli (Reber, 1989). However, they may not be able to explicitly articulate the complex rules that they have learned.

Seger (1994) argued that implicit learning satisfies several criteria: (i) subjects are not conscious of what they have learned and as mentioned above cannot articulate it; (ii) the information learned is complex in the sense that it is not simply based on correlations or counts of frequencies; (iii) the learning gained is not based on hypothesis testing or explicitly trying to find patterns, but essentially people acquire information incidentally through other cognitive processes than those that might be employed through explicit, deliberate and directed learning. Since people with amnesia apparently do as well on implicit learning as others, the neural basis of such learning is quite different from that involved in tasks based on episodic memory. A meta analysis of implicit learning in amnesic patients was carried out by Kessels and Haan (2003). The neural basis of implicit learning is reviewed in (Reber, 2013). Implicit learning is typically robust in the sense that the learning does not fade over time, for example Agus, Thorpe, and Pressnitzer (2010) showed how newly acquired sound patterns would be retained for weeks. A meta-analysis has also been shown that people with autism spectrum disorders do well on implicit learning (Foti, De Crescenzo, Vivanti, Menghini, & Vicari, 2015).

Apart from the obvious example of language, implicit learning is important for such skills as surgery (Masters, Lo, Maxwell, & Patil, 2008), where was found that learning by observation and without explicit verbal instruction produced results that were particularly useful in the multi-tasking environment of a surgical operation. In a similar vein Vine, Masters, McGrath, Bright, and Wilson (2012) showed that gaze strategies of experts could be learned implicitly in the training of laparoscopic skills, similar to a result that had earlier been shown using VR (Wilson et al., 2011). Bailenson et al. (2008a) showed how implicit learning of motor tasks (Tai Chi) exploiting VR could be accomplished. This also involved observation—of a self-avatar seen from third person perspective and in a mirror, of recorded movements of themselves and a teacher. The affordances offered through stereoscopy outweighed viewing the same movements on a video with respect to ultimate performance. Also using VR (Bell & Weinstein, 2011) showed how people with psychiatric disability would improve their job interview skills by taking part in a simulated job interview. Pan, Gillies, Barker, Clark, and Slater (2012) report an experiment where males who are socially anxious about meeting women learn to reduce their anxiety after a conversation with a virtual woman, that intersperses mundane conversation (e.g., what work do you do?) with more personally alarming discussion (e.g., do you have a girl friend?), even though there was no explicit attempt at all to influence the participants in this direction. It as if the participants incidentally learned through the mundane conversation that there was nothing to fear from such an interaction, and then were able to carry this learning over to the more personal aspects of the conversation at a lesser level of anxiety.

In all of the above examples the information to which people were exposed was directly related to what was being implicitly learned: to implicitly learn a grammar subjects were exposed to sentences, to implicitly learn Tai Chi or surgery subjects observed examples. In the next Section we move on to a quite different form of implicit learning—where the stimuli are not related to what is being learned except in a quite indirect manner.

## 2.3 Implicit Change Through Virtual Body Ownership

### *2.3.1 The Proteus Effect*

In Sect. 2.1.3 we introduced the concept of virtual body ownership, the perceptual illusion that a virtual body coincident in space with the person's real body will be perceived as their own body. Here we examine the consequences of such transformed body ownership.

The first work on these lines was by Yee and Bailenson (2007) who introduced what they termed the 'Proteus Effect'. (In modern parlance we might refer to the god Proteus as a 'shape shifter'.) Their observation was that the appearance and actions of a person's digital self-representation in both online non-immersive environments and in VR affects their behavior. For example, they showed that people in a collaborative VR moved closer or not to virtual representations of others depending on whether the face of their own virtual body was judged more or less attractive than their real one. People with taller virtual bodies were more aggressive in a negotiation task than people with shorter bodies. A similar result has been reported by Freeman et al. (2013) in a study of paranoia—that people seeing the virtual world from a taller perspective (without actual embodiment in a virtual body) were more confident in being with others than those with a point of view that was shorter.

Groom, Bailenson, and Nass (2009) used the Proteus Effect to examine racial bias. In the context of a simulated job interview they embodied White people in a Black virtual body that they saw reflected in a virtual mirror for 1 min in a HMD, with visuomotor feedback restricted to head movements. A racial Implicit Association Test (IAT) (Greenwald, McGhee, & Schwartz, 1998) showed that there was greater bias in favor of White after the embodiment.

The Proteus Effect is explained by Self Perception Theory (Bem, 1972) where it is argued that people will infer the attitudes of others from inferring their behavior in a situation, and also apply the same to themselves—i.e., infer their own attitudes by inferring this from their own behavior. Yee and Bailenson (2007) also argue that there is a stereotyping effect, that people behave in a situation according to how others would expect a person with such a body to behave. These theories might explain the racial bias results of Groom et al. (2009) since participants were placed in a social situation (a job interview) where racial bias is known to operate.

However, it would not explain results where there is no social context and there are no behavioral demands on participants—they simply observe their own virtual body from first person perspective or in a mirror. Most importantly they cannot explain changes that occur as a result of embodiment that would not be expected to be associated with transformed body ownership, or which are not under the control of participants. For example, it has been observed that the RHI results in a cooling of the associated real hand (Moseley et al., 2008), and Salomon, Lim, Pfeiffer, Gassert, and Blanke (2013) showed that this applied to the whole virtual body.

### *2.3.2 The Multisensory Framework*

In the multisensory framework people see their virtual body from first person perspective usually with another type of sensory input consistent with the virtual body being their own. This may be visuotactile stimulation, where objects seen to touch the virtual body trigger corresponding feelings of touch on the real body (as in the RHI), or visuomotor synchrony, where through real-time motion capture the virtual body is programmed to move synchronously and in correspondence with real body movements, or both (Kokkinara & Slater, 2014).

Theoretical underpinnings of body ownership have been formulated by Blanke, Slater, and Serino (2015). This includes (i) multisensory integration of proprioception, (ii) top-down body-related visual information in peripersonal space, (ii) embodiment in the sense we have described above. These requirements are clearly satisfied with virtual embodiment that includes first person perspective and visuomotor synchrony. It was further argued in (Banakou & Slater, 2014), that since whenever in our whole lives we have looked down towards ourselves we have seen our body. Moreover, in normal healthy conditions whenever we move our limbs we see them move. There is therefore, in the context of virtual embodiment, overwhelming evidence that when there is embodiment with first person perspective and visuomotor synchrony that the simplest perceptual hypothesis for the brain to adopt is that the virtual body is our own body, irrespective of how much it looks like our body or not. As has been empirically found in the Proteus Effect sometimes this change of body carries with it other changes at the attitudinal, behavioral, physiological, and cognitive levels.

In a study of racial bias Peck, Seinfeld, Aglioti, and Slater (2013) embodied light-skinned females (15 per group) in either a dark-skinned virtual body, a light-skinned one, a purple one, or no body. The body in all cases was seen directly from first person perspective and in a virtual mirror, and with visuomotor synchrony. Those in the 'no body' group saw a reflection at the geometrically correct place in the mirror, but with visuomotor asynchrony. Prior to the experiment the racial IAT was administered, and again after the experiment. The period of embodiment was about 12 min, during which time participants were only required to move and look towards their body, and 12 virtual characters, half of them Black and half of them White walked past. It was found that there was a decrease in IAT indicating a reduction in implicit racial bias only for those who had been in a light-skinned body. That a few minutes embodied in a Black virtual body could reduce implicit racial bias seemed unlikely, however, using only a black rubber arm in the RHI, Maister, Sebanz, Knoblich, and Tsakiris (2013) found a similar result. In a subsequent study Banakou, PD, and Slater (2016) again embodied 90 White female participants in a White or Black body. Each had 1, 2 or 3 exposures with visuomotor synchrony following the movements of a virtual Tai Chi teacher. However, the IAT was administered first one week before the initial exposure, and one week after the final exposure. It was again found that those in the Black virtual body showed a clear reduction in implicit bias, independently of the number of exposures, whereas this did not occur for those in the White virtual body. This indicates that the reduction in racial bias may be sustained, and that a single exposure is sufficient for this.

The above relates only to implicit attitudes, however, changes have been found due to embodiment in other domains. Kilteni, Bergstrom, and Slater (2013) embodied 36 people in one of two different bodies: 18 in a body resembling Jimi Hendrix (dark skinned, casually dressed) and the rest in a formally dressed light-skinned body. Their task was to play hand drums. The virtual hand drums were registered in space with real hand-drums. There was visuomotor synchrony since participants would see their virtual hands moving with their real hand movements, both directly and in a mirror, and visuotactile synchrony since as their hand was seen to touch the virtual drums they would feel this because their real hand would simultaneously strike the real drum. Through real-time motion capture the extent to which participants moved their upper body was recorded (they were seated with their legs holding the drums in place). It was found that those in the more casual, dark-skinned body exhibited much greater body movement than those in the formal light-skinned body. Participants had no idea about the purpose of the experiment, since it was between-groups and therefore they could not know about the other type of body used.

The drumming example is concerned with behavioral change. However, strong perceptual changes can also be induced with transformed body ownership. van der Hoort, Guterstam, and Ehrsson (2011), using the technique of streaming video data to an HMD, embodied people in a Barbie doll body or a giant manikin body. This was used together with synchronous visuotactile stimulation. They observed that in the first case subjects overestimated object sizes and in the second case underestimated. Banakou, Groten, and Slater (2013) took this one step further using virtual embodiment to show that the *form* of the body and not just the size influences this perceptual result. Adult participants were embodied either the body of a child of about 5 years old or in an adult shaped body but shrunk down to the same size as the child. Visuomotor synchrony was used in addition to seeing the body from first person perspective and in a mirror. The same result was found, that on the average participants in these small bodies overestimated object sizes. However, the degree of overestimation of those in the child body was around double that of those in the shrunk down adult body. Moreover using an IAT that tested between self-attribution of child-like or adult-like attributes, those in the child body condition self attributed more towards the child-like than the adult-like. In another condition that used visuomotor asynchrony all these differences disappeared.

Our next example illustrates a cognitive change. Participants were asked to explain a pressing personal problem to a character on the other side of a virtual room (Osimo, Pizarro, Spanlang, & Slater, 2015). They were embodied in a virtual body that was a very close likeness of their real body. The virtual person to whom they explained their problem (referred to as the Counselor) was either a virtual rendition of Dr. Sigmund Freud, or another copy of themselves. After explaining their problem they were shifted to the body of the Counselor and saw and heard their initial incarnation explaining the problem. Then as the Counselor they could reply back to themselves offering advise as to how to resolve the problem, after which they were re-embodied back in their original body as themselves, and saw and heard (with a disguised voice) a replay of the advice of the Counselor (in fact their own advice). They could keep swapping back and forth between self-embodiment or embodiment as the Counselor hence maintaining a conversation. Therefore this setup was an objectification of 'talking to oneself' except that the 'one' spoken to was represented as a virtual person. In each embodiment the participant would see their virtual body directly from first person perspective and in a mirror. The conditions of the experiment were that the Counselor was a copy of themselves or of Freud, and that as Counselor they experienced visuomotor asynchrony or synchrony. It was found that although in all conditions there was an improvement in the rating of their mood in relation to the person problem, the best improvement was when they were embodied as Freud with visuomotor synchrony. This produced a strong level of body ownership and agency with respect to the Freud body. In other words being embodied as Freud gave them access to different mental resources, allowing them to better able move towards a solution to their problem, than being embodied as another copy of themselves.

In the next section we consider these findings in the context of implicit learning.

### 2.3.3 Embodiment and Implicit Learning

All of the above examples show how transformed body ownership can lead to changes. Although this was not the goal of those studies, for the purposes of exposition we can reformulate them as 'learning' studies. For example, to learn how to show less racial bias in an IAT, to learn how to resolve a personal problem through talking to different representations of yourself, to learn how to play the drums with greater vigor.

In Sect. 2.2.2 we saw that there are a number of criteria that implicit learning has to satisfy: what is learned is non-conscious, it is complex, it is not as a result of hypothesis testing, and it is not based on episodic memory. If we take the racial bias as an example, there is no conscious attempt in the procedure to influence implicit racial bias. In fact participants in these between-group experimental designs only experience one body type. What is being learned is complex—an IAT is a complex response-time based procedure. There is clearly no hypothesis testing or deliberate attempt to learn something based on episodic memory. People simply have an experience.

In these cases the effects are implicit, but the information that generates the implicit changes is seemingly quite different from implicit learning. For the latter the data for learning is directly and closely related to what is to be learned—e.g., sentences generated by a specific grammar. In the case of body ownership the information is only indirectly related. In the self-talk example—the self-conversation with Freud—no coaching whatsoever was given about how to address personal problems in a more productive way.

Our hypothesis is that simply having experiences from another perspective embodied in another body results in implicit change. When the body is related to an 'issue' (e.g., racism) then the change will be within that domain, even though there is no explicit information whatsoever about racial bias in the experience. This also conforms to the view of Gallagher (2005) who discusses the relationship between body and mind. When the type of body conforms to what is to be learned then this will aid learning over and above what can be learned through explicit learning.

## 2.4 Summary

This paper has reviewed the major concepts of virtual reality, in particular presence (the illusion of being in the virtual place, and the illusion that events there are really happening) and also how virtual reality can be used to produce virtual body ownership—a virtual body coincident in space with the real body and seen from first person perspective can generate the illusion that it is the person's body. We have reviewed how presence has been used in education, and also discussed the notion of implicit learning. Our discussion then led to the observation that virtual body ownership can lead to implicit changes, so that, for example, when a person embodies a body of different race their implicit bias against people of that race may decrease. This is similar to what happens in implicit learning, even though the approaches are quite different. We then reached the conclusion that learning may be enhanced when participants are embodied in a virtual body that is appropriate for that type of body. For example, someone learning how to be an orchestra conductor might best be embodied in the body resembling, for example, Leonard Bernstein; learning opera Luciano Pavarotti or Maria Callas; or learning ballet Natalia Osipova. This remains an interesting hypothesis to test with controlled experimental studies.

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