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# Is The Subjective Feel of "Presence" an Uninteresting Goal?

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## Abstract

An ideal goal of virtual reality technology is to deliver a complete visual and sensorimotor duplicate of an object: a fully integrated haptic and visual set of stimuli that would make us feel as if we are in the "presence" of the real object in an ordinary situation. The goal is very ambitious, but what is a measure of success? An analysis of presence is much needed, and one of the main tenets of our paper is that an empirical study of the psychological aspects of the feel of presence would constitute the pivotal element of such an analysis; we shall argue that some interesting lessons can be learned about the ideal goal. To sustain our argument, we consider two case studies in turn. The tunnel effect case teaches us that actual stimulation is neither necessary nor sufficient to convey presence. The picture case teaches us that it is possible to learn how to interact to a high degree of success with very impoverished stimuli and successfully compensate for poor stimulation. Research should be thus oriented not towards potentially useless and costly "duplication" of reality, but towards the unexplored potentialities offered by new and complex interfaces.

## Key words

Presence. Realism. Object perception.

## Introduction. Photorealism and non-photorealism

The development of *realism* in computer graphics and of virtual reality represents an important challenge for computer science. This effort in computer science raises a number of questions related to the challenge of creating increasingly realistic environments and of establishing a naturalistic interaction with computer mediated situations. Perceptual studies, cognitive sciences and philosophy are sometimes invoked both because of the feedback of these developments onto the analysis of human representation of reality and of object perception, and in order to assist computer science creations with the understanding of perception and cognition acquired in the scientific and philosophical domain. However, it may simply be the case that the working notion of realism owes much to a common-sense interpretation of the "duplication effect" offered by virtual reality and aimed at by realism, and is not adequately grounded on sound psychological research.

In the early days of computer graphics, the goal was to accurately reconstruct the appearance of a still object or scene. This kind of realism is called "photorealism", like the artistic movement which began in the late 1960's in which scenes are painted in a style closely resembling photographs: the subject matter is usually nondescript, the true focus of a photorealist painting being the very way the reality is reproduced. Early photorealism in computer graphics gave much importance to accurately reproducing the geometry and light reflection properties of surfaces. As the production of animated graphics has increased, a new standard of realism has become important: "dynamic" realism in which the behavior of animated characters, of natural phenomena and of the physical conditions of the environment (such as collisions, falls, etc.) take center stage [1, 2, 3]. There are, accordingly, many varieties of realism, from geometry and modeling, to rendering, to behavior and interaction; and then many degrees and techniques for achieving realism. Virtual reality for instance is strongly committed to the handling of real-time interaction, which reduces the time available for processing geometry complexity, rendering, behavior simulation, etc. In any case, we can define photorealism as the craft of creating computer generated scenes that appear so convincing that they are perceptually indistinguishable from photographs or films. Any rendering style that does not try to create a photographic look is termed non-photorealistic; this includes, to give an example, scientific-diagrammatic visualization, the creation of caricature cartoons, the emulation of traditional artistic media. Interest in non-photorealism has spread within the computer graphics community only lately [4]. It is said that non-photorealistic rendering allows much freedom in the manipulation and expression of ideas, that it permits to stress only the important characteristics of the depicted scene, that it permits to create in a simpler way. An interesting point here is the difference between a quest for realism and a quest for *believability*. Photorealism intends to approximate the model, the real world, in a very accurate way, and this involves taking into account an enormously complex geometry, as well as a bewildering variety of object features and lighting conditions. Indeed, the world is very complicated to model. This is the reason why non-photorealism doesn't attempt to provide a "one-to-one" reproduction of the reality but is after creations that are believable, which include only those details which are considered relevant or representative of the intention behind the model.

One of the questions we would like to address is whether a non-photorealistic environment is able induce a sense of "Presence"* in virtual environments – of "being there", or of having an object "in front of us in full flesh". Some further aspects of this question may be spelled out. Is it *necessary* to mimic physical reality in order to produce computer mediated phenomena which enhance the sense of Presence experienced by the user? Is it *sufficient* to reproduce the details of the geometry and illumination of real objects? What is the role of the reproduction of their physical behavior and interactions? What is the role of the interactions mediated by sense modalities other than vision, such as the haptic sense or of audition? And does the active participation of the user play at all a role?

## Presence: perception and interaction

Different authors conceive Presence as a *subjective feeling* and as a *multidimensional construct*. As a subjective feeling, Presence is construed as the private sensation of the user of "*being there*" in the virtual environment, which overcomes the impression of being in a laboratory room, facing a computer screen or a virtual reality device.

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* We shall use the capitalized word "Presence" to express the relatively technical notion of *being there*.

> "Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another" [5, p. 225].

The intended sense of presence is then a form of *illusion of non-mediation* [6] in which the user fails to perceive the mean for administering the stimuli corresponding to the virtual objects, such as the computer screen or the head-mounted display. In a sense, it is as if the screen or the display have become 'transparent' – one is no longer aware of the mediation they provide. This perceptual phenomenon is made possible by different factors: realism, richness of peripheral stimulation, multi-sensory dimensions of the experience, attentional factors, social richness, involvement of the participant, the possibility of acting within the medium, and the symbolic and cultural meaning of the environments and activity.

There is consensus that the experience of presence is a complex, multidimensional form of perception, formed through an interplay of raw (multi-)sensory data and various cognitive processes – an experience in which attentional factors play a crucial role as well. [7]

There is still little evidence about the weight of these different factors in the makeup of Presence, but the current approaches appear to suffer from a lack of analysis of the concept of Presence and of the specificity of Presence in virtual reality. Very often the question of Presence in virtual environments is mixed up with discussion about other kinds of mediated activities, such as reading a book, watching TV, looking at a picture, and also interacting with text-based virtual environments. [8, 9] It is important to highlight some differences between these various activities.

First, reading a book or interacting with a text-based environment is a purely symbolic experience. It hasn't the perceptual characteristics of the interaction with sounds, images, haptic sensations that are proper to the experience with complex virtual environments, and which constitutes one of the specific innovations of computer sciences. The user of virtual reality interacts with the "synthetic" environment through non-symbolic systems, such as the perceptual and the motor system. One can be perfectly immersed in the literary world of Huckleberry Finn without receiving any visual or tactual stimulation that corresponds to one's experience, say without being able of experiencing the physical sensation of shaking the hand of his hero.

On the other hand, within the limits traced by the development of software and hardware systems, a "virtual object" is something one can have the impression of touching, seeing, and actively modifying [10]. Artists that make use of virtual reality for their creations have explored many sensory channels of interaction [11]. A recently developed technology, for instance, allows the user to interact with 3D works of art through touch, thank to the mediation of so-called haptic interfaces that provide the sensation of manually exploring digital models of existing sculptures. A museum of digital sculptures is being created, and the sculptures are perceptually accessible to users that are situated far from the original work of art or that cannot enjoy them visually. [12, 13] *Multisensoriality*, that is the coordinated use of multiple sensory channels, is a primary goal and a crucial characteristic of ideal virtual systems.

This form of interaction could also be directed towards the creation of new types of works of art, entirely digital ones, and to the creation of virtual perceptual objects that have no equivalent in the "hard" reality [14]. The second of the specific innovations linked to virtual reality is then the possibility of actively intervening and interacting with the synthetic environment, both relatively to the point of view of the user or his movements, and as regards the modifications he is able to bring about in the world of artificial objects. Virtual systems are then based on a form of *sensorimotor loop*, in that the user has the possibility of acting and moving in the virtual environment in order to modify the objects in it and then to gain new perceptual information from them; the incoming perceptual information is then used in order to better adjust movements in the artificial environment.

> "Action reveals information, which guides further action, which reveals additional information, and so on." [15, p. 1]

This (active component is not available in "simple" perceptual media such as photography or cinema. The experience of the user in virtual environments is then peculiar because it is both *perceptual* (multisensory) and *interactive* (sensorimotor). The action-perception cycle is typical of *enactive knowledge*, a form of knowledge which is acquired by doing and perceiving the consequences of one's own actions, instead than by utilizing iconic or symbolic representations or instructions (an in the case of purely visual medias or of symbolic medias such as language). Enactive knowledge seems then to fit well with virtual reality interfaces that allow a (almost) complete multisensory and sensorimotor interaction with virtual objects.

Because the virtual world is perceptual, a symbolic or cultural based explication of Presence may be insufficient for explaining what it is to believe in the acceptability of a virtual environment. It is hence necessary to deal with the problem of the objects and events of the virtual world in terms of their perception and of the interaction the user can establish with them.

We cannot in fact address, let alone solve, the problem of producing virtual environments that are able of conveying a strong "sense of Presence" if we continue to treat it as a question of promoting a mysterious, unarticulated and at best unspecified subjective feeling. On the contrary, if the problem of Presence regards the perception of a world with its objects and events, it is on the side of the *mechanisms of object perception* that we can search for an answer.

## Object perception. The non-necessity of the complete-stimulus situation.

Let's consider a first case of object perception. I'm looking at my cat; the cat is in the garden, behind the fence. Even if I don't see all of the body of my cat, the cat is somehow present in front of me as a complete animal, and not as a strange combination of disconnected segments of a cat, separated by pieces of wood. Besides, even when the cat is in front of the fence, I see it as a complete cat, not as a cat-like convex and furry surface with no interior and no back side.

This is an example of an object which is present for perception without a complete and detailed stimulus condition. Consider now a balloon. I hold it in my hand, then I throw it in the air; I catch it and throw it again, and so on. In the time span in which the balloon doesn't touch my hand I do not receive any tactile stimulation from it. Even if I am blindfolded, and I don't see the balloon in the air, I continue to "perceive" the balloon in the absence of a material stimulation of the receptors. The interruption of contact doesn't make the balloon "disappear". It follows that the complete and detailed reproduction of the stimulation from the balloon does not seem to be a necessary condition for the perception of real complete objects.

The examples of the cat and of the balloon are instances of what we may term the “generalized tunnel effect”. An object that enters at one and of a tunnel and reappears at the other end could be seen as an object that enters in the tunnel and is destroyed out of sight, followed by an indistinguishable object which is created inside the tunnel and exits at the other end. This way of describing the situation is compatible and certainly reliably correlated with the pattern of presence and absence of sensory stimulation corresponding to the object. However, the visual system in many a condition possesses the resources for delivering the impression that *only one* object is there, which survives the passage through the tunnel. An explanation is needed for this impression, which entails that the object is taken as being there when it is not stimulating our sensory organs.

Consider briefly two models, a peripheral-sensory model and a less peripheral tracking model. According to the peripheral-sensory model, sensory systems integrate or *fill in* the missing information (say, the parts of the cat that are behind the fence). The phenomenon of the filling in or completion of gaps in the visual images is extremely common, as shown by the unawareness of the retina’s blind spot: in spite of the absence of receptors in that area, we do see a continuous and uniform world, and not a hole in our field of view. In the same way the emicranic patient of Ramachandran, when pointing his scotoma on a picture on the wall, doesn’t see a hole in its place, but a normal wall, with its uninterrupted plaster or wallpaper [16]. *Filling in* is not the result of a general cognitive hypothesis, since there are cues that are easily completed and cues, such as corners of squares, that are difficult to fill in. Moreover, different kinds of visual information (texture, color, form) have different times of completion.  Filling in is then a perceptual mechanism, but not necessarily a central reconstruction meant to produce a complete image (picture-like) of the visual scene.

It is possible, as suggested by [17] that the seeming completeness of the visual scene is the product of the sensorimotor nature of perception. Let us take a case in some sense complementary to those of the cat and the balloon. In our new condition an observer is presented with a very detailed scene, say, a picture of Notre Dame of Paris; the vision is interrupted by a slight flicker and then the picture immediately reappears, with a major change in it. Typically observers miss the change. It is remarkable that in some cases the observer can be looking directly to the change area (in this case the change regards position of the cathedral in the picture, which is shifted of about 10 degrees), without noticing anything. This phenomenon has been called “change blindness” [18]. It is not limited to flickers, but can be obtained with cunning manipulation of eye saccades, blinks and film cuts. Even if it looks as if we perceived all of a scene with its details, in fact it doesn’t seem that the visual system stores great amounts of information in the form of complete internal representations the scene which is being seen. In this sense there is no need for filling in mechanisms that should complete the gaps between the mental representations and the real external scene.

According to the defenders of the sensorimotor account, the world itself can in fact function as its own memory or representation, at least when basic perceptual and motor behaviors are at stake. Anytime we need to retrieve the relevant information, all we have to do is point our attention to the relevant area. This availability of relevant information accounts for the impression of seeing everything in the scene, as happened for the impression of seeing all of the cat behind the fence.

The thesis can be easily generalized. When we handle a glass we do not feel as if we were touching just the part of the glass we are in fact touching, but we have the experience of holding the whole glass itself in our hand. *Motor possibilities* seem to be relevant in building up the perceptual experience of the object. In fact, the visual and haptic systems are better conceived of not as a plate where the world image is passively impressed as a whole, but as perceptual and motor systems that explore the environment by directing the attention now on some details, then on others, and that exploit the information involved in the movement of the scene, of the eye and head or of the hand. When observing a cat behind a fence, the visual system is able to make the cat “appear” and “disappear” simply by displacing the eyes or the head, slightly changing its perspective or point of view. The subsequent modification of the appearance of the object contains crucial information for the identification of the shape, localization and other relevant properties.

According to this view, the motor ability is not an optional component of seeing, but a constitutive one. The same thing is true for the haptic system. In the case of the haptic perception of the quantitative characteristics of an hand-held object (a stick, for instance), [19] suggests that the haptic system is sensitive to the variations of the rotational inertia of the system constituted of the arm, hand and object. For instance, when wielding two objects of the same weight but different volume, one tends to perceive the smallest as the heaviest.

This well-known phenomenon, called ‘size-weight illusion’, has received many different explanations, for the most part based on cognitive mechanisms tied to the perceptual expectancies produced by the volume and the triggering of consequent motor program. [20] proposes a totally different kind of explanation based on the fact that the hand system is both motor system and a sensory system, thereby highlighting the role of the so-called muscular sense (or kinesthetic sense) in the perception of the characteristics of external objects (exteroception), and not only in proprioception. An hand-held object in fact presents a specific mass distribution relatively to the hand. This distribution varies with the variations of the extension and shape of the object, but not with the object’s weight. The mechanoreceptors present in the muscles are sensitive to the resistance that the object opposes to being moved (inertia, specifically: rotational inertia, since the movements relative to the joints are rotations), as when handling it, or lifting. The resistance opposed by the object and the mass distribution are strictly correlated and their relation is described by a complex value called inertia tensor. The perception of the weight and of the geometric characteristics of the object (length, width, shape, orientation) varies with changes in different components of the inertia tensor (moments and products). In the case of the size-weight illusion the variation of the distribution of the masses and of the inertia tensor of an object created on purpose, with no variations in the weight, in the global shape or in the volume of the object, provokes different weight evaluations, thus demonstrating that the variations in the characteristics of the inertia tensor are significant for the perception of the weight of hand-held objects. Hence, it is important to take into account the existence of such motor mechanisms if one wants to “realistically” reproduce the haptic effect provoked by hand-held object without reproducing the bare physical characteristics of the object itself.

On to top the peripheral-sensory model, one may consider a less peripheral object-tracking model. According to this model, the impression or feeling that the whole cat is there (although only part of it is visible) and not a the result of a sensory mechanism, but of a higher level integration. So called ‘object-files’ have been appealed to in the literature to account for the perceptual survival of objects in the absence of continuous sensory information [21]. When an object is the focus of attention, it is assigned a mental file which is kept alive for a while in case the object disappears. When the object reappears, a file is assigned to it and then merged with the previously created file. Under the object-file hypothesis, the sense of Presence could be explained as the activation of an object file.

By appealing to recent psychological literature we have shown the *non-necessity* of the *completeness of the stimuli* condition for the perceptual impression "as of" complete, uniform objects, and also for the task of recognizing and tracking a complex object. The perceptual system is capable of identifying, recognizing and tracking objects even from non-detailed, gappy stimulation. At the same time we have shown that the "point to point' reproduction of a stimulus may be *not sufficient* for perception, because different mechanisms, such as motor components, are intrinsically part of the perceptual process.

We can draw a first lesson for virtual reality ambitions from this cursory examination of some elemental cases. In virtual reality too, delivering a complete visual duplicate of an object is then neither necessary nor sufficient in order to produce the impression of an object. It is not the fidelity to the real model (the world) that makes the synthetic environment looking and feeling real, but the fidelity to the perceptual conditions involved in the mental construction of perceived objects. This fidelity can be attained by taking into account the specific sensorimotor determinants of visual perception, or some higher level features such as object files. The believability of synthetic objects depends on the adequacy of the reproduction of the relevant aspects of the perceptual mechanism involved, and not on the realism of the reproduction of the stimulus.

## Perceptual mechanisms of simplification and integration. Complete stimulation is not sufficient.

It is important to know, and to be ready to exploit, the mechanisms of *perceptual integration* and *simplification*. In natural conditions, in fact, the perceptual system has to deal with a great wealth of information of different kinds. In the case of a moving object, for example a red toy car which is moved along a racing circuit, information about the trajectory and velocity has to be calculated, and information from the visual, kinaesthetic, tactile, and even auditory stimuli has to be integrated. [22] describes a particular relationship between the curvature of a trajectory (a geometric characteristic) and the tangential velocity of the stimulus (a cinematic property): when tracing and ellipse with one's own arm, the velocity of the arm decreases in the most curved parts, the relationship being described by a mathematical law called '2/3 power law'. This law also controls the perception of the passive movement of one's own arm or of a spot light moving in front of the observer. In fact, the manipulation of the velocity in disagreement with the correlated curvature ray induces perceptual illusions that tend to restore the violated law. The relationship or co-variation of the geometric and cinematic properties is just one of the mechanisms that the brain has at its disposal for reducing the number of degrees of freedom to be controlled and for simplifying both the programming and production of movements and the structuring of perception [22].

The same is true when the perceptual system is requested to take into account the information provided by different sensory modalities. The task seems to be non-problematic, since we normally perceive a coherent world through many sensory modalities at the same time. But what happens when information from different modalities is discrepant, when the sensory modalities present conflicting contents? It is worth noting that in the case of slight discrepancies between sensory modalities, the final percept that results from their integration is often coherent. If, for instance, a square is presented to the observer as being 5 cm long by sight and then 10 cm long by touch (through the use of minifying lenses), the subject will continue to perceive one and only one object (he will integrate the partial percepts in one and the same perceived object) [23].

The perceptual system then can employ strategies devoted to avoiding the construction of incoherent objects. In other cases the discrepancy and the perceptual conditions can be such that the subject perceives two different objects (the partial percepts are not integrated in one and the same object). When it is suitable for the perceptual system to combine the two partial percepts in a coherent unit, the perceived object can take different aspects, in that one sensory modality can dominate over the other (this is the case of the so-called "ventriloquist effect", in which visual information "attracts" auditory information: the result is that we perceive the voice as if it came from the doll, that is, where we see the lips moving) or that the sensory modalities assume a similar weight (in the example of the haptic-visual square the perceived size can be midway between the judgments expressed with vision only and with touch only). In any case, the perceptual system intervenes actively on the incoming information in order to maintain coherence: the cases of overt perceptual conflict (an object that feels in some way and looks in another) are in fact rare. The differences in the adopted solution can depend on many different reasons: the kind of stimulation, the degree of discrepancy, the sensory modalities involved, the allocation of attention, the perceptual and cognitive context, past experience, are all conditions that are susceptible of having an influence on the perceptual outcome.

The question is: What makes the perceptual system "choose" between separating the discrepant percepts or including them in a unit? What makes it adopt dominance as opposed to compromise? Specific acquaintance with the event being perceived and general acquaintance with the sensory modalities involved, can in fact affect the observers' assumption of unity (whether the stimuli are to be considered as coming from one and the same source or from two distinguished objects) and thus the perceptual outcome. The result of a strong assumption of unity is a perceptual outcome consonant with a single physical event. The assumption of unity can be influenced by the experimenter's instructions, and other cognitive hypotheses and considerations. Some authors have found it useful to re-formulate this condition in terms of expectancies.

> "It is a truism worth repeating that the perceptual effect of a stimulus is necessarily dependent upon the set or expectancy of the organism" [24, p. 206].

However, contrary to this classical statement, the existence of directive processes in perception that operate on the incoming stimulus and organize the perceptual field in such a way as to maximize percepts that are coherent with current expectations and needs and to minimize those percepts that are discrepant relatively to expectancies and needs, need not be a truism. This hypothesis assumes that the violations of perceptual expectancies and the incongruities with the organism's needs pose a problem to the organism. Confirmation of expectancies in fact has a central role, in that whenever well-established expectancies fail of confirmation, the organism may envision dramatic perceptual reorganization. A corollary hypothesis is that a (conspicuous) mismatching with (well-established) expectancies is, as long as possible, actively avoided and "*the organism will ward off the perception of the unexpected*" [25, p. 208].

The hypothesis is apparently confirmed by an experiment performed with playing cards and described in [25]. The subjects of the experiment are exposed to normal (five of hearths, ace of hearts, five of spades, seven of spades) and trick playing cards (i.e. black three of hearts or red two of spades). Incongruity provokes four possible reactions: dominance, compromise, disruption and recognition of the incongruity. Dominance and compromise reactions are characterized by a perceptual denial of the incongruous elements in the stimulus pattern; in the first case form or color dominates and the subject perceives a normal card, i.e. a normal, red three of hearts instead of a black one, or a black three of spades. The perceptual result then meets the expectancies about normal playing cards. In the second case a compromise object is perceived which composes the conflict, i.e. a grayish three of hearts. When the subject cannot solve his task of recognition there is disruption. The recognition of the incongruity is accompanied by a sense of wrongness: the subject suddenly or gradually begins to feel that there is something wrong with the stimulus; this sensation can turn to disruption or give rise to recognition of the incongruity. The subjects of the experiment then manifest a resistance to incongruity between the actual stimulus and their own expectations. When the incongruity is not suitably modified the subject has the sensation that something is going wrong since he is faced to an ambiguity that he can accept (recognition) or not (disruption). In the case of disruption the violation of the coherence reveals to be paralyzing: ambiguity is a hard condition to be managed by action and perception. The experience of perceptual conflicts can be considered as analogous to the failure in perceptual recognition, since it diminishes the efficiency of the organism.

The study of the specific quantities (such as the inertia tensor for dynamic touch) to which the perceptual systems are sensitive is important in order to understand which are the stimuli that are taken into account, independently of the physical characteristics of the world. in the same vein, the study of the mechanisms used by the perceptual system in order to face and eventually solve perceptual discrepancies is an important step on the way towards understanding how the perceptual system moves from the treatment of simple stimuli to the perception of complex, coherent objects.

## The lesson of ordinary pictures

If Presence is not only a technologically hard but possibly also an unnecessary goal, what lessons could be drawn about the design of interfaces for handling virtual realities? Should we just give up the quest for complex interfaces?

Not so quickly. Over and above photorealism there are other interesting directions in which one may want to look. Consider ordinary static 2-d pictures, such as dinner-party photographs or drawings. When looking at a picture we have the feeling that the depicted object is somewhat "present", although we know perfectly well that we are not in front of the object itself; we may even know that the object no longer exists. This diminished feeling of presence did not prevent ordinary pictures from being one of the most successful representational devices ever; indeed, one of the most successful devices *tout court*. One of the reasons of the success of drawings and photographs may lie in the very fact that pictures are sacrificing some of those very elements that may instead help conveying a stronger feel of presence. The fact that a picture is static and gives only a partial representation of an object could be a huge advantage for some cognitive queries one may want to address to pictures. For instance, one can explore visually a picture in a way which may not be available for an ordinary object. If it is the cognitively “central” element of *attention* that is at stake, and not the relatively peripheral and phenomenal feel of presence, then static pictures are *better* cognitive devices. In such a case, clearly less is more.

## Conclusions

We have suggested that the question of Presence in virtual environments should not be faced as an attempt to just reproduce or enhance the subjective feeling of the user of being translated in another situation.

We have also suggested to tackle the problem of presence by establishing a wider spectrum of conditions that make a virtual object present to the user of a virtual environment.

In order to avoid confusion, we prefer to maintain the use of the term ‘presence’ for the subjective feeling of being there as it is the term in use in the virtual reality literature, and to adopt the term 'believability' for referring to the problem of presence as a matter of construction of credible virtual objects. The evaluation of virtual environments should then be presented in terms of the conditions that make virtual objects and virtual environments believable or credible for the user.

The two questions of Presence and believability are related, and the relationship between Presence as the feeling of being there and the feeling that the object is present to the user represents an issue to be investigated. [26] suggests to address the question of establishing "Where am I" (in the science-fiction case in which my brain is split from my body and the two have different locations) by referring to the location of my point of view: I am where my point of view is. In the interaction with a virtual environment then I am 'there' if my point of view is there in the virtual world and not, for instance, here in the laboratory room. But the problem of the point of view is a more complex one. First of all, we always see, touch, and in general perceive the objects from a point of view. Moreover, we do not strictly perceive all the details and features of an object at the same time. [17] claims that this fact doesn't affect the presence of the object in perception: the object is present even if we do not see its occluded parts, the occluded parts being potentially present, that is to say present in our sensorimotor interaction with the object. The problem of the point of view could then be related to that of the sensorimotor interaction with the objects, its exploration and the relative changes in the point of view that exploration makes possible.

As to the question of the believability of virtual objects we have sampled a number of psychological issues and have suggested that the faithful reproduction of all the details or features of the object is neither a necessary nor a sufficient goal for attaining credibility. The study of object perception is a promising field for finding indications for the construction of credible virtual objects and environments; in particular the research on the perceptual mechanisms that guide the integration of different stimuli, or stimuli from different modalities, and the simplification of the perceptual task, seems to be promising.

The existence of cognitive and perceptual expectancies relatively to the objects that are to be perceived seems to play an important role in the appearance of the perceived world. Previous training with specific virtual objects, the availability of suitable instructions and the exploitation of strong perceptual assumptions are then three possible directions to be explored. They may enhance the credibility of virtual environments, since they can create and modify expectations, and then modify, to a certain extent, the appearance of the virtual objects. The mechanisms implied in the resolution of intersensory discrepancies and the mechanisms of simplification of the perceptual task that have been cited in this paper can also be exploited in order to guide and modify the appearance of the virtual objects.

The role of expectations could also play a role in the evaluation of the credibility of virtual objects, and constitute a test for believability. When a credible object is present to the user the latter forms expectations about it and about the (perceptual) consequences of the interaction with it, even if not all the features of the object are actually perceived. Expectations are not necessarily expressed in linguistic terms. Implicit forms of expectation are included into the motor programs that guide the reaching of an object (as in the case of the pre-shaping of the hand) or the catching of a ball (as in the example of the balloon which is thrown in the air and caught again). It is possible to observe and even to measure the motor behaviors connected with these forms of expectation (for instance through the use of sensors applied on the hands of the user). This measure can be expressed quantitatively, and this is an advantage relatively to the qualitative character of the questionnaires that are actually in use to evaluate Presence.

A final consideration regards the role of the sensorimotor loop in the experience of perceived objects, that is the role of the exercise of motor abilities in perception. As we have seen, the motor components are not merely accessory to the perceptual activity, but play a prominent role in the perceptual experience of the world. In particular they seem to determine the sense of presence of the objects to the perceiver in their wholeness even when only parts of the object are directly accessible to the senses. The construction of interfaces that exploit the sensorimotor loop (enactive interfaces) seems to be a major concern for believability. Enactive interfaces enable the user to act and to perceive the consequences of his action in such a way as to create strong connections between his movements and his perceptual experiences. In the mean time, perception can then constitute a guide for action in the virtual environment.

**Acknowledgements**

Reserach for this paper was partly funded by the European Commission 6th PCRD Network of Excellence "Enactive interfaces". Elena Pasquinelli's work was further funded by Percro lab. Elena Pasquinelli would like to thank researchers of Percro lab for enriching discussions and for the possibility of testing virtual

reality systems and haptic devices.

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