# Empathy with Computer Game Characters: A Cognitive Neuroscience Perspective

India Morrison[*]
[*]University of Wales Bangor
School of Psychology
Centre for Cognitive Neuroscience
Gwynedd LL57 2AS, UK
pspc46@bangor.ac.uk

Tom Ziemke[*]
[*]University of Skövde
School of Humanities & Informatics
PO Box 408, 54128 Skövde, Sweden
tom.ziemke@his.se

**Abstract**

This paper discusses recent findings concerning the brain mechanisms underlying visuomotor, visuotactile, and visuo-affective mappings and their relevance to understanding how human players relate to computer game characters. In particular visuo-affective mappings, which are regarded as the foundation for the subjective, emotional elements of *empathy*, come into play especially during social interactions, when we transform visual information about someone else's emotional state into similar emotional dispositions of our own. Understanding these processes may provide basic preconditions for game character identification and empathy in three main cases discussed in this paper: (1) when the game character is controlled from a first-person perspective; (2) when the character is controlled from a third-person perspective; and (3) when the character is seen from a third-person perspective but not controlled by the player. Given that human cognition springs from neural processes ultimately subserving bioregulation, self-preservation, navigation in a subjective space, and social relationships, we argue that acknowledging this legacy - and perhaps even regarding it as a path through design space - can contribute to effective human-computer interface design.

## 1 Introduction

Much recent research on *embodied cognition* has been concerned with the way cognitive and emotional processes are shaped by the body and its sensorimotor interaction with the world (e.g. Varela et al., 1991; Clark, 1997; Damasio, 1999; Sheets-Johnstone, 1999). To some degree, the role of the body has also been addressed in human-computer interaction research (e.g. Dourish, 2001) as well as in computer games research (e.g. Wilhelmsson, 2001; Juul, 2004). The actual brain mechanisms underlying the mapping of visual to body-related information, however, have received relatively little attention in these research communities. This paper therefore discusses recent findings in cognitive neuroscience concerning the brain mechanisms underlying visuomotor, visuotactile, and visuo-affective mappings and their relevance to understanding how human players relate to computer game characters. In particular we address *visuo-affective* mappings, which constitute the foundation for the subjective, emotional elements of *empathy*, as they transform visual information about someone else's emotional state into similar emotional dispositions of our own.

When you are moving about in the world, your brain is using visual information from your eyes to guide and coordinate the movements of your body. In doing so, the brain faces a basic computational problem: how to turn *visual* information from the sheets of retinal cells in the eye into *motoric* information on the cortical map of the body. Considering the enormous number of degrees of freedom involved, this is by no means a simple computational feat, and it represents one of the most crucial issues in cognitive neuroscience. We shall argue that neuroscientific "eye-to-body-representation" research can provide useful guidance in designing computer game characters - especially when one wishes to enhance a sense of *identification* or *empathy* on the part of the user.

The rendering of "third-person" visual information into "first-person" information in body-centered terms can be thought of as a transformation function. Information about the world as it meets the eye (in retinal coordinates) is transformed into an "egocentric" frame of reference, which consequently allows visual information about the world to be translated into specific actions taken by the body. The understanding of our own and others' behavior relies at least in part on such transformations from visual field information to body-centered information. Sometimes this information deals with objects in space, sometimes with the location and sensation of body parts, and sometimes with basic emotional reactions.

These considerations are pertinent to computer game character design, because it is exactly this sort of transformational mapping that allows a user to interface with, and to control, characters that appear as figures on flat displays. Here we outline some computational constraints on user-character empathy. Although derived directly from recent discoveries from cognitive neuroscience, they are discussed on a conceptual level here, with as little anatomical detail as possible. We believe that taking these constraints into account can aid effective design of computer game characters and user interfaces.

## 2 Mapping visual onto body-related information

When we play a video game, we are using tools (such as a joystick) to direct actions on behalf of a character navigating though a flat visual display of Cartesian space. Let us call the position of the hands on the joystick the *veridical position* in space, and the hand movements made while moving the joystick the *veridical actions*. Correspondingly, we shall call the spatial locations and movements of the character in the Cartesian display of the game-world the *apparent positions* and the *apparent actions*. The question then becomes, how do we come to feel as if the apparent positions and actions are veridical?

To address this question, the following sections will describe findings concerning three kinds of mappings: *visuomotor*, *visuotactile*, and *visuo-affective*. Visuomotor mappings occur when objects in the coordinate system of external space are transformed into a coordinate system of which the body and its effectors (*e.g.* hands, arms) are at the center. An example of this is when we navigate through apparent positions in a gameworld, using the joystick to act upon objects within the gameworld as if our veridical hands were actually in that world's space. Likewise, visuotactile mappings are those in which visual and touch information become integrated into the brain's representational body schema. Finally, visuo-affective mappings comprise a relatively new category at the focus of an emerging field of emotion-related research (Carr *et al*, 2003; Adolphs, 2004; Keysers *et al*, 2004; Wicker *et al*, 2004; Morrison *et al*, 2004; Singer *et al*, 2004; Jackson *et al*, 2005; Morrison, forthcoming). Visuo-affective mappings come into play especially during social interactions, when we transform visual information about someone else's emotional state (on the basis of facial expressions or other relevant cues) into similar emotional dispositions of our own. It is this type of mapping that is regarded as the foundation for the subjective, emotional elements of empathy.

There are multiple ways, then, in which our own self-related motor, sensory, and emotional representations can be altered dynamically on the basis of visual input. Each of the above types of mapping is bound up with the question of how the brain handles apparent positions and actions as if they were veridical. In turn, they all have bearing on how the human user becomes situated in the game world, and thus on the extent to which users may identify or feel empathy with game characters.

Visuomotor, visuotactile, and visuo-affective mapping processes may provide basic preconditions for game character identification or empathy in three major ways: (1) when the game character is controlled from a first-person perspective; (2) when the character is controlled from a third-person perspective; and (3) when the character is seen from a third-person perspective but is not controlled by the user. In (1), the user sees the apparent world as if through the eyes of the character they control. In (2), on the other hand, the user sees the game character as a figure on a screen, from a third-person perspective. The third case covers game characters which are seen from the third-person perspective but are not controlled by the user, such as enemies, allies, or bystanders.

## 3 Agency from a first-person perspective

Seeing the apparent world through the eyes of the character you control is probably the most straightforward case. First of all, the apparent space and objects you see are encountered from a first-person perspective, and their properties may thus suggest immediate *affordances*, i.e. opportunities for action (Gibson, 1979).

Second, since there is no need to translate from third- to first-person visual perspective, it bears a greater resemblance to the kind of retinal-to-sensorimotor mapping that occurs in everyday life. Neuroimaging studies by Perani *et al* (2001) and Han *et al* (2005) found that different networks of the brain were activated for real and virtual worlds. Although these differences were probably influenced by differences in the visual realism of the scenes, activity in a part of the brain associated with spatial cognition (superior parietal cortex) did *not* differ between viewing agents in the real and virtual worlds.

Even so, the context of the task has been found to be important for the way the primate brain achieves visuomotor mappings in spatial reference frames (Wise, 1996). The mapping is "standard" when the task involves a stimulus that guides the action by virtue of its perceived affordances, such as reaching out and grasping an object on your desk. Depending on the interface device, some first-person game character actions may simply call for standard mappings.

When a mouse or joystick is used to effect apparent actions, however, "non-standard" mappings are more likely to be required. Moving a character's hand *upward* on the screen, for example, requires a veridical movement of the user's hand *forward* in a horizontal plane. In other kinds of nonstandard mappings the relationship between the visual stimulus and the response movement is arbitrary - the stimulus location does not indicate the appropriate action or movement direction (Toni *et al*, 2001; Murray *et al*, 2000). For example, an object's color (but not its shape or location) could instruct a target location, movement direction, or type of action. Arbitrary mappings apply for many video games.

Gorbet *et al* (2004) investigated the brain areas involved in nonstandard visuomotor mappings of varying complexity. They found that even though different patterns of brain activity emerge as the complexity of nonstandard motor mappings increases, the number of coactivated areas in a network and spatial extent of activity does not increase. In fact, cortical activity can *decrease* with practice on a task (Raichle, 1998). This implies that even for complex nonstandard motor mappings, ease may be achieved with practice. The human brain's ability to learn nonstandard mappings appears to have generous bounds, and provides much latitude in game and interface design space - especially for games which will be played repeatedly and for which skill is part of the thrill. Where the aim is to achieve interactive fluency with minimal practice, though, game and interface designs involving standard or simple non-standard mappings may be preferable.

Experiments with both monkeys and humans have suggested that vision can guide perceptions based on information from other, less spatially acute, modalities such as touch and proprioception (Graziano *et al*, 1999; Pavani *et al*, 2000; Lloyd *et al*, 2003). Temporal correlations between tactile and visual events can also produce a "proprioceptive drift" that pulls veridical touch sensation and position sense into line with their apparent counterparts (Spence *et al*, 2000). These phenomena fall under the heading of "visual capture", which is a function of the way the brain integrates information from multiple sensory modalities. A good example of this is the so-called "rubber hand illusion" in which an artificial hand obscures a subject's view of their own hand. When the artificial hand and the out-of-sight real hand are touched at the same time, the touch sensation feels as if it is actually coming from the artificial hand (Botvinick & Cohen, 1998; Ehrsson *et al*, 2004). Visual capture can actually result in the mislocalization of a tactile stimulus in the visual field.

Visual capture occurs partly because of differences in the acuity and probabilistic reliability between vision and other sensory modalities. Also, the primate brain's visual representation of the space surrounding the body ("peripersonal space") overlaps with body-part-specific tactile and motor representations in certain areas of the brain. Moreover, peripersonal space representation does not follow exactly the same rules that apply to the space beyond our own bodies ("extrapersonal space"). Peripersonal space can be thought of as a virtual envelope around the surface of the skin.

The special representational rules of peripersonal space mean that the corresponding visual receptive fields in the brain are independent of gaze orientation or retinal mapping, but instead are co-registered with and anchored to specific body parts. In other words, the brain's visual representation of the space around your hand does not change when your eyes move over the visual scene, but does change when you are touched there or when your hand itself moves about in space (Rizzolatti & Matelli, 2003; Jeannerod, 1997). This is because the *same* neurons in the brain are doing the job of representing *both* the tactile field and the vision of its surrounding peripersonal space.

Similarly, other experiments have shown that visual information can be mapped onto motor representations (Maravita & Iriki, 2004). Again, the mapping function depends on the elegant bimodality of visual and motor neurons for a given receptive field (say, for the hand). The dynamic nature of visual receptive fields in a motor-related area of the monkey brain means that using a tool extends the representation of the hand and arm to include the tool (Iriki *et al*, 1996). Similar results have been found in humans (Maravita *et al*, 2002). The anecdotal experience of Cole *et al* (2000) attests to the ease with which the brain can extend a sense of agency alongside a dynamic adjustment of visually-influenced body representation. In remotely manipulating robot arms via virtual-reality goggles and a servo apparatus, they found: "Making a movement and seeing it effected successfully led to a strong sense of embodiment within the robot arms and body. This was manifest in one particular example when one of us thought that he had better be careful for if he dropped a wrench it would land on his leg! Only the robot arms had been seen and moved, but the perception was that one's body was in the robot" (Cole *et al*, 2000).

# 4 Agency from a third-person perspective

In many computer games the user controls a character that is seen from a third-person point of view, and in those terms is indistinguishable from the other figures in the display. This case most resembles the conditions under which we observe the behavior of other people in everyday life. Being social creatures, humans and other primates possess neural mechanisms which facilitate the interpretation of the actions of others in immediate, first-person terms. How is this accomplished?

In the previous section we saw that the brain often employs an elegant computational solution for mapping visual and motor or tactile representations onto each other: by the existence of bimodal neurons that respond in *both* domains. A similar neural mechanism is at play in transforming visual information about actions performed by others into egocentric motor representations. In this case the special bimodal neurons are called *"mirror neurons"*, found in premotor cortex, a motor-related area of the primate brain that subserves action planning (di Pellegrino *et al,* 1992; Rizzolatti & Craighero, 2004; Buccino *et al,* 2004a). The important feature of mirror neurons is that observed actions are put immediately in egocentric terms. Mirror neurons were first discovered by recording directly from brain cells in monkeys, but further neuroimaging research in humans has shown that a similar system exists in human brains as well (Iacoboni *et al,* 1999; Grezes *et al,* 2004).

This kind of mapping mechanism from apparent to veridical actions appears to have functional counterparts in the domain of emotion. *Emotion* is understood here as a coupling of perceptual information with a variety of responses, including motor, autonomic, and endocrine, which dispose the organism to act (cf. Damasio, 1999). This perspective places emotion in the context of processes responsible for preparing and generating such responses, as well as remembering and anticipating situations which may call for specific responses. Recent neuroimaging and neurophysiological studies have demonstrated that visuo-affective mappings can occur for *pain* (Hutchison *et al,* 1999; Morrison *et al,* 2004; Singer *et al,* 2004; Jackson *et al,* 2005), *disgust* (Wicker *et al,* 2004), *touch (*Keysers *et al,* 2004) and *fear* (Olsson & Phelps, 2004). Such results are interpreted as a neural basis for empathy (Preston & de Waal, 2002; Gallese, 2003; Decety & Jackson, 2004), and can be taken into consideration in the design of computer game characters and scenarios.

Preliminary evidence for mirror-neuron-like visuo-affective mapping mechanisms in pain networks came from a neurophysiological study recording directly from cortical cells of human volunteer patients awaiting brain surgery (Hutchison *et al,* 1999). This effect was corroborated in healthy subjects in an fMRI experiment by Morrison *et al* (2004). Volunteers underwent stimulation of one hand by a needle-like sharp probe while in the scanner. In another condition, they watched videos of someone else's hand being pricked by a hypodermic needle. The results revealed common activation in a pain-related brain area for both feeling and seeing pain. The locus of overlapping activity fell squarely within the recording site reported by Hutchison *et al*.

A similar result was obtained by Singer *et al* (2004). Here, female subjects viewed their own hand alongside that of their romantic partner as electrode shocks were delivered to one or the other at either high or low levels of stimulation. Visual cues projected on a screen behind the hands indicated to the subject whether the shock would occur to herself or to her partner, as well as whether the stimulation would be low (not painful) or high (painful). In another fMRI experiment, subjects viewed photographs of a demonstrator's hand and foot encountering a variety of everyday mishaps, such as being slammed in a car door or cut with a knife while slicing cucumbers (Jackson *et al*, 2004).

Patients with lesions to a cortical area involved in nausea (the anterior insula) show a selective deficit in recognizing facial expressions of disgust (Calder *et al,* 1997, Adolphs *et al,* 2003). These findings have also been supported in healthy subjects using fMRI (Phillips *et al,* 2000). Consistent with this, Wicker *et al*'s (2003) fMRI investigation of disgust showed overlapping activation in the same brain area when subjects smelled offensive odors in the scanner and observed demonstrators' disgusted reactions to the smells. Similarly, Olsson and Phelps (2004) have shown that the mere observation of someone receiving shocks (following particular cues in a fear conditioning task) can give rise to physiological reactions as if the observer were in for a shock herself.

# 5 Uncontrolled agents from a third-person perspective

Visuomotor mechanisms like mirror neurons and visuo-affective mechanisms found in other sensory and emotion-related domains can facilitate a user's identification with the character's "body" as well as providing the groundwork for empathy. But for non-controlled agents, sometimes it is not desirable for the user to identify or empathize with the figure on the screen (enemies). In other cases, one would wish to foster such identification or empathy (allies), or to remain more or less neutral (bystanders).

There are several factors that can influence the kinds of processing discussed in the previous sections. One factor is the degree of similarity between the observed agent's motor actions and the motor repertoire of the user. Another factor is the degree of resemblance to humans. A third is the realism of the display. Finally, the behavior of the agent in relation to other agents is also important.

Using fMRI, Buccino *et al* (2004b) found that mirror system responses did not differ significantly when humans viewed other humans, dogs, and monkeys biting a piece of food. This is probably because biting is an action category common to the motor repertoire of all three species. However, when the subjects viewed the same three species making species-specific mouth movements (talking, barking, lip-smacking), different networks were activated. The observer's (or user's) degree of expertise in a depicted set of actions would also contribute to the degree of motor-related activity in the brain (Calvo-Merino *et al*, 2005).

Because motor repertoires are so dependent on body plan, this can mean that even differences in the basic body plan from the human can influence the perception of action. But even when the superficial resemblance to a human is slight (aliens, etc.), if the agent moves like a human, it is more likely to be interpreted as being humanlike.

Even so, there is evidence that *emotional* reactions to faces are modulated on the basis of factors like familiarity (Pizzagalli *et al*, 2002) and in-group membership (Phelps *et al*, 1998). Similarity may also be a factor in empathy (Preston & de Waal, 2002).

Realistic movement parameters are also important; for example, the more rigid movements of a robot arm have been shown to interfere markedly less with one's own arm movements than human arm movements (Kilner *et al*, 2003) and to influence the allocation of attention (Castiello, 2004).

It is intuitively obvious that the realism of display would play a part in the extent to which the user becomes engaged the gameworld, and this is borne out by neuroimaging research into how the brain processes virtual world-spaces. Perani *et al*'s (2004) study showed that seeing real (video) hands in realistic environments activated motor cortices in the subject's brain, but equivalent actions performed by a very geometrical virtual hand did not. Similarly, Han *et al* (2005) found motor-related activity when real (video) humans were viewed, but not in response to cartoon representations or unrealistic virtual worlds.

Despite such similarities and differences in visuomotor and affective engagement with noncontrolled agents, it does not take very much for humans to anthropomorphize even simple animate agents or to make personality trait attributions to geometrical shapes or point-light figures (Heberlein & Adolphs, 2004; Heberlein *et al*, 2004). Individuals with autism spectrum disorders (Zimmer, 2003) and patients with brain damage to an important part of the brain implicated in social cognition (the amygdala) do not spontaneously attribute social-type intentions to geometrical shapes moving with respect to one another (Heberlein & Adolphs, 2004). Neurologically normal individuals, on the other hand, need very little provocation to interpret a triangle as "chasing" a square or to think that the triangle is "mean" and the square is "frightened" (Zimmer, 2003). Likewise, the gaze direction and orientation of third-person agents can draw users into making, and acting upon, social inferences about the direction of attention or even the intentions of the agent (Allison *et al*, 2000).

# 6 Summary

Human computer game users, unlike their gameworld counterparts, are grounded in a rather messy biological legacy of blood and bone. Our cognition springs from neural processes ultimately subserving bioregulation, self-preservation, navigation in a subjective space, and social relationships. Based on recent findings in cognitive neuroscience, concerning the brain mechanisms underlying the mapping of visual onto body-related information, we have tried to show in this paper that acknowledging this legacy - and perhaps even regarding it as a path through design space - can contribute to effective human-computer interface design.

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