Université de Liège

Faculté de Psychologie et des Sciences de l'Education

THE VISUAL PROCESSING OF SELF-REFERENTIAL STIMULI:

DO WE PROCESS OUR OWN FACE DIFFERENTLY FROM OTHER FACES?

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Sous la direction de Serge Brédart

Jury de thèse composé de Nuala Brady, Serge Brédart, Axel Cleeremans, Fabienne Collette et Michel Hansenne

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RÉSUMÉ

Lorsque nous pensons à nous-mêmes, à toutes les caractéristiques physiques ou psychologiques qui nous définissent, à tous les objets que nous possédons, nous avons l'impression qu'ils ont un statut bien particulier dans notre esprit, qu'ils sont spéciaux pour nous. Notre propre visage est certainement parmi l'une des plus uniques et distinctives de toutes ces informations autoréférentielles. Dans ce travail, nous nous sommes penchés sur les spécificités du traitement visuel du propre visage.

Dans un premier chapitre théorique, nous avons questionné la possibilité d'utiliser le traitement du propre visage comme un indice de conscience de soi (voir Chapitre 1). Ensuite, nous avons passé en revue les différentes études existantes qui concernaient la spécificité du propre visage ou d'autres informations autoréférentielles (voir Chapitre 2). Suite à cette revue de la littérature, il est apparu que l'intuition selon laquelle notre propre visage est un stimulus spécial n'avait pas pu être confirmée unanimement par les études qui nous précédaient.

Ce travail ambitionnait donc d'évaluer empiriquement dans quelle mesure notre propre visage est traité par le système cognitif de façon différente des autres visages que nous rencontrons. Nous avons tenté de répondre à cette question selon trois angles différents. Tout d'abord, nous nous sommes intéressés à la précision de la représentation de notre propre visage en mémoire. Pour cela, nous avons utilisé dans notre première étude une méthode psychophysique permettant de déterminer dans quelle mesure nous sommes capables de détecter des modifications fines apportées à des photographies de notre propre visage (voir Chapitre 4). Ensuite, nous avons examiné si la reconnaissance de notre propre visage, mais aussi celle de notre propre corps, sont sous-tendues par des zones cérébrales spécifiques. A cette fin, au cours d'une seconde étude, nous avons utilisé l'imagerie par résonance magnétique fonctionnelle (IRMf, voir Chapitre 5). Enfin, nous avons testé si le propre visage est particulièrement apte à capturer ou à retenir notre attention lorsqu'il est présenté de façon inopportune alors que nous sommes occupés à réaliser une tâche sans

rapport (voir Chapitres 6, 7 et 8). Pour ce faire, nous avons eu recours, dans une série de trois études, à différents paradigmes attentionnels : un paradigme de jugement de parité, un paradigme de cécité attentionnelle, et un paradigme de recherche visuel lors duquel nous avons procédé à l'enregistrement des mouvements oculaires des participants.

Tout au long de ce travail, nous avons adopté une approche visant à différencier les effets d'autoréférence de simples effets de familiarité. Pour ce faire, dans toutes nos études, nous avons comparé les réponses obtenues lors de la présentation du propre visage du participant à celles obtenues lors de la présentation du visage d'une personne hautement familière pour le participant (un ami ou un collègue du même groupe d'âge et du même sexe). Par ailleurs, dans les études attentionnelles, les réponses subséquentes à la présentation de ces deux visages familiers étaient également comparées à celles obtenues suite à l'apparition de visages de personnes inconnues. En somme, si les performances obtenues sur le propre visage et le visage très familier différaient, nous pourrions penser que ces différences sont dues à l'aspect autoréférentiel du propre visage. Par contre, si les performances ne différaient pas entre le propre visage et l'autre visage très familier mais que ces deux visages se distinguaient des visages inconnus, nous pourrions supposer que nous sommes face à de simples effets de familiarité.

La première étude psychophysique a montré que la représentation que nous avons en mémoire de notre propre visage est très précise. Cette précision est seulement limitée par les capacités de discrimination perceptive de notre système visuel. Cependant, il en était de même pour le visage d'une autre personne hautement familière. De ce point de vue, il ne semble donc pas que notre propre visage soit spécial. Néanmoins, il semblerait que cette représentation soit sous-tendue par des substrats cérébraux spécifiques, comme indiqué par notre seconde étude en IRMf. Cette étude a aussi montré que notre propre corps serait également traité par des régions cérébrales spécifiques. De plus, certaines régions seraient dédiées au traitement abstrait de notre propre apparence physique puisqu'elles étaient impliquées indépendamment du type de matériel présenté (visage ou corps). Enfin, nous avons montré, grâce aux trois études attentionnelles, que le propre visage n'est pas un distracteur exceptionnel par rapport à d'autres visages familiers. En effet, le propre visage ne semble pas capturer l'attention de façon automatique. Il semblerait que le propre visage bénéficie simplement d'une allocation de l'attention préférentielle par rapport à des visages inconnus. En d'autres termes, l'allocation de l'attention au propre visage est sujette à diverses contraintes (par exemple sa localisation spatiale) et il semblerait que l'attention soit nécessaire pour identifier le propre visage en tant que tel.

Cet ensemble de résultats est discuté dans un dernier chapitre (voir Chapitre 9) où nous tentons de mettre les données provenant des trois perspectives différentes (représentation en mémoire, substrats cérébraux et propriétés attentionnelles relatifs au propre visage) en rapport. De plus, la possibilité d'utiliser le propre visage comme outil d'étude de la conscience de soi ou de différents processus cognitifs (reconnaissance ou attention visuelle) est brièvement passée en revue.

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PREAMBLE

When we think about ourselves, about the traits that define us, about the physical characteristics or the objects that we own, we have the intuition that they have a special status in our mind. We deeply feel that they are different from everything else in the world. Let us start with a trivial example. Imagine that you are wandering with your family on a flea market on a Sunday afternoon. Suddenly your eyes fall on the exact same toy that you were fond of when you were a child and that you had completely forgotten. You cannot imagine that you would pass your way indifferently then. You surely would be seized by positive emotions and memories. You would probably feel like picking the toy up and handle it a short while or showing it to your spouse and children that are with you.

Other examples of the importance of self-related information can be found in far more dramatic situations. Accounts from the Second World War describe how prisoners of the Nazi camps urged to see their own face if it happened that one of them found a tiny piece of mirror (Antelme, 1957). Seeing their own face was experienced as finding themselves back for a little while after their identity had been wrecked by Nazis (e.g., all their personal belongings had been confiscated and their names had been replaced by numbers tattooed on their arm, see Levi, 1987). Jonathan Cole (1999) has described in a whole book how life of people dealing with problems touching their own face (e.g., disfigurement, facial paralysis, etc) is affected. These terrible examples illustrate how our own face is an essential component of our identity besides other self-related information such as our own name. Since the discovery and the propagation of photography, passports or driving licences from all over the world have in common the presence of the name, of course, but also of an identity picture.

The present work aims at studying the specificities of self-referential stimuli. Self-referential stimuli can be defined as all the information pertaining to oneself (see Figure 1). This information can concern abstract characteristics such as our own beliefs, tastes, or personal goals. It can also refer to more physical characteristics such as the appearance of our own face, our weight, size and so on. Some authors (Fenigstein, Scheier, & Buss, 1975) have distinguished public (i.e., visible from outside) from private (i.e., invisible private events) self-information. To anticipate a little bit over Chapter 1, different levels of self-information have been linked to different levels of self-awareness (Morin, 2006). Public self-information would be known by perceptual components of self-awareness while we would access private self-information with more conceptual levels of self-awareness.

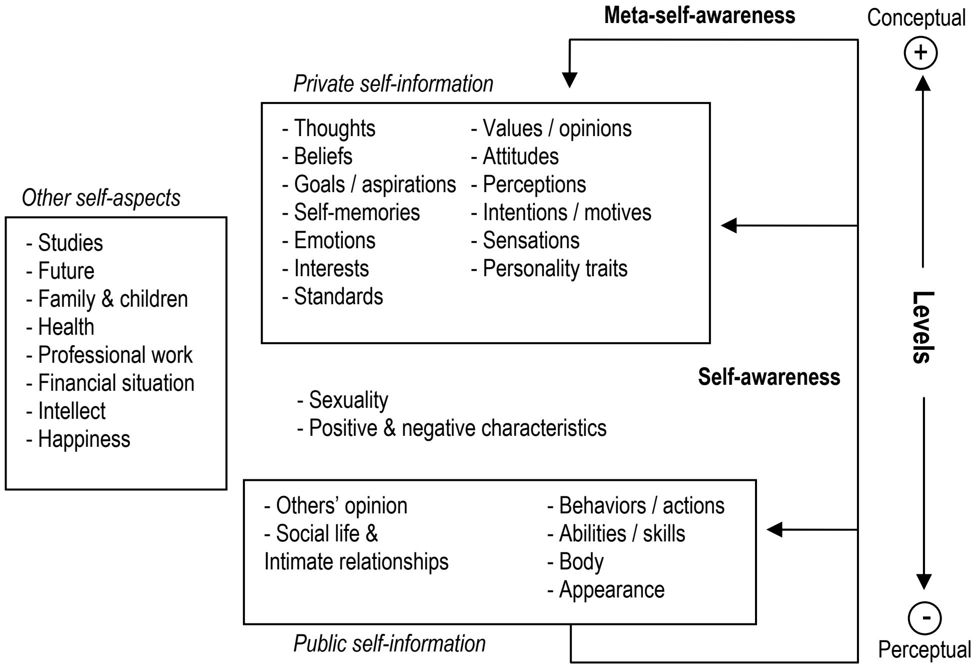

Figure 1. Schematic illustration of different kinds of self-information in relation with different levels of self-awareness (from Morin, 2006).

In the present thesis, we focused particularly on the self-face. The reason of this choice is that the self-face is probably the most distinctive among those stimuli pertaining to oneself. Indeed, contrary to other self-related information that can be shared with other people (e.g., our first name, our hometown, our food preference, and so on) our own face is a unique self-referential stimulus. Nonetheless, it is still unclear from the existing literature whether the importance of the self-face for his or her owner and its high level of distinctiveness gives rise to specific processing (e.g., Heatherton, Macrae, & Kelley, 2004, but see Gillihan & Farah,

2005) or not. Therefore, we will try to give an update on the existing literature investigating this matter and bring new data in order to answer this question more precisely.

The two first chapters of this thesis will present reviews of the literature to date about self-referential stimuli. First, in Chapter 1 we will ask whether the presentation of self-referential stimuli can be an efficient way to investigate self-consciousness. After having given an operational definition of self-consciousness, we will try to answer this important question according to four perspectives: a developmental approach, a comparative approach, and a neurocognitive approach focusing on the one hand on healthy subjects and on the second hand on populations suffering from alterations of self-consciousness. Second, in Chapter 2 we will examine whether self-referential stimuli are really special. In other words, we will survey findings of previous studies that have assessed whether self-referential stimuli are processed differently and elicit specific responses by comparison with other stimuli that do not pertain to oneself. We will describe previous studies investigating self-referential stimuli according to three different topics: their representation in memory, the neural correlates subtending their processing and their attentional properties.

After this summary of the existing literature, we will introduce our own practical work in Chapter 3. We will describe in more detail our choice to investigate the self-face and the original approach we have used to do so (i.e., assessing the specificity of the self-face by comparison with other personally familiar faces).

In Chapter 4 we will present our first study in which we measured the accuracy of the memory for our own face by means of a psychophysical method. In Chapter 5 we will describe a functional magnetic resonance imaging study in which the neural correlates of visual self-face and self-body recognition were examined. In Chapter 6 to 8 we will report three studies evaluating the attentional properties of the self-face. Finally, we will close this work with a ninth and last chapter discussing our findings in regard with the previous literature.

Chapter 1

PROCESSING SELF-REFERENTIAL STIMULI AS AN INDEX OF SELF-CONSCIOUSNESS?

1. Conceptions of self-consciousness[1]

Some authors have investigated the processing of self-referential stimuli with the assumption that it can be a direct way to investigate self-consciousness. But what is self-consciousness? In some people's eyes, it is the most fundamental issue in psychology (Rochat, 2003). Indeed, some see this phenomenon as the manifestation of the highest level of cognitive abilities (see Morin, 2006 for a review). Self-consciousness has constituted a central question in philosophy for a long time and only recently has become the subject of increasing systematic investigation (and excitement) in cognitive neuroscience (Gallagher, 2000). However, if each of us has a more or less precise idea of what the term "self-consciousness" refers to, it is undoubtedly among those concepts in psychology that do not make unanimity. So what exactly is self-consciousness? This term actually refers to a whole spectrum of different processes and abilities as a function of the definition ones adopts. The amount of existing different definitions is probably innumerable. In the present section, we will thus not seek to be exhaustive (while voluntarily neglecting philosophical debates) and will try to present the most usual and operational of these definitions of self-consciousness.

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[1] As no unanimous distinction exists between « self-consciousness » and « self-awareness » (except that "self-consciousness" is sometimes used in the sense of reflective consciousness while "self-awareness" encompasses more perceptive aspects of one's subjective experience, e.g., Zeman, 2005) we will hereafter use these two words as synonymous.

1.1. Self-consciousness and consciousness

First of all, it might be useful to distinguish self-consciousness and consciousness. “Consciousness” is also an ambiguous term that pertains to a virtually infinite numbers of definitions and theories (Zeman, 2001). It is thus crucial not to confuse these two phenomena. Indeed, they are independent, produce different effects and therefore should not be equated even if there exist interconnections between them (Morin, 2006; Zeman, 2001).

Consciousness covers different dimensions. Zeman (2001) distinguish three of them: (1) the *waking state*, implying the capacity to perceive and to respond to environmental stimulations, by opposition with those states (non-REM sleep or coma) where people are unconscious; (2) *experience*, that is, the ‘online’ subjective content of our experience from moment to moment. In that sense, we are conscious *of something*. This is the case for instance, when we perceive the smell of coffee coming from the kitchen in the morning; (3) *mind*, that is, the propositional content of our mental states, our desires, our goals, our believes, and so on. Trying to find an operational definition to start studying consciousness, Christof Koch (2004, p. 11) cites John Searle (1997) to whom “consciousness consists of those states of sentience, or feeling, or awareness, which begin in the morning when we awake from a dreamless sleep and continue throughout the day until we fall into a coma or die or fall asleep again or otherwise become unconscious”. This definition encompasses the same aspects that highlighted by Zeman (2001). For our present purpose of finding an operational definition of self-consciousness, defining consciousness as *being awake and having an experience* (of any kind) seems satisfying. Note that an important aspect of consciousness is its subjectiveness and privateness. Indeed, the access to our own mental states is restricted to ourselves and they cannot be accessed from the outside in the same manner (Kircher & David, 2003).

Self-awareness would in turn occur when we start to reflect on our experience and are explicitly aware of the content of consciousness (meta-consciousness, Schooler, 2002). Similarly, self-awareness has been defined as the ability to become the object of one’s own attention and to process self-information (Morin, 2006), or to become aware of one’s own states as one’s own states (Newen & Vogeley, 2003). From a phenomenological perspective, self-consciousness has been described as our knowledge "that we are the same person across time, that we are the authors of our thoughts/actions, and that we are distinct from our environment" (Kircher & David, 2003, p. 445). What seems to differentiate consciousness from self-awareness is thus their content. Mead (1934, see also Duval & Wicklund, 1972) already defined consciousness as the focus of attention outward, that is toward the environment and self-awareness as the focus of attention inward, that is toward the self. Kircher and David (2003, p. 449) express a similar view when they write that "in the same way that we think we are in direct contact with the world, although it is mere construct in our brain, we feel in direct contact with ourselves". Note that restricting consciousness as a focus outward might at first appear misleading. Indeed, how should internal stimulations such as hunger or pain be classified? Are we automatically self-aware of our interoceptive sensations because they are coming from inside or are we just conscious of them if we feel and perceive them but do not think about them? According to Kircher and David (2003), pain is tacitly self-conscious because it is perceived from a first-person perspective. This point leads us to three main features of our experiences supposed to characterize self-consciousness (Metzinger, 2003). The first one is the *unity*, when we realize that we form a coherent whole, in other words, self-coherence (Kircher & David, 2003). The second feature is constituted by the feeling of *ownership* (I know that I am the one who is doing, feeling or thinking something) and *agency* (I am the one who caused and controlled this action or this thought). The last feature is the *perspectivity* we adopt, that is a first-person-perspective by opposition with a third-person-perspective.

In an interesting framework reviewed by Morin (2006), self-consciousness is integrated in a scale comprising different levels of consciousness (see Table 1). These levels gradually rise from unconsciousness to self-awareness, consciousness being positioned in the middle as a prerequisite for self-consciousness. As a matter of fact, self-awareness apparently implies consciousness (you could not be conscious of experiencing something that you are not experiencing) while the reverse is not necessarily true (a conscious being is not always capable of self-awareness and a being capable of self-consciousness is not conscious at every moment of the content of its consciousness). Self-awareness has thus often been described as a superior form of consciousness. An ultimate level of consciousness would be “meta-self-awareness”, that is the ability to become aware that you are self-aware (see Morin, 2006).

Levels	Definition	Related concepts
Meta-self-awareness	Being aware that one is self-aware	- Consciousness5 - Extended self
Self-awareness	Focusing attention on self; processing private & public self-information	- Consciousness4 - Extended & private self - Symbolic self - Meta representational self-consciousness - Conceptual self-consciousness - Self-concept - Reflective, recursive, self & meta-consciousness
Consciousness	Focusing attention on the environment; processing incoming external stimuli	- Non-conscious mind - Ecological & interpersonal self - Neocortical level - Consciousness3-6 - Sensorimotor awareness - Core, peripheral, primary & minimal consciousness
Unconscious	Being non-responsive to self and environment	- Consciousness6 - Non-consciousness - Arousal - Limbic stage - Sensorimotor cognition

Table 1. Summary of recent neurocognitive proposals on levels of consciousness and self-awareness (from Morin, 2006).

1.2. Levels of self-consciousness

Exactly like consciousness, self-consciousness is a multi-faceted concept (Zeman, 2001). It can take different forms corresponding to different levels of cognitive abilities (Newen & Vogeley, 2003).

Zeman (2001) reports five different meanings for self-consciousness: (1) *Proneness to embarrassment:* in that sense, self-consciousness corresponds to the consciousness we have about others’ consciousness about ourselves. According to Zeman, such a self-consciousness implies embarrassment in the company of others. It is thus a quite high-order process in which self-consciousness is seen as a link between consciousness of self and of others; (2) *Self-detection:* this definition reflects the ability of an organism to respond to stimuli directed towards it or to change its behaviour as a function of the consciousness it has about its own actions; (3) *Self-recognition:* according to some authors (Gallup, 1970; but see Heyes, 1994; Mitchell, 1997), the capacity to recognize oneself in the mirror implies the possession of a basic self concept, reflecting a certain degree of self-consciousness. It has been studied extensively among primates and human children. This topic has brought extremely controversial debates as whether this kind of self-consciousness can be equated with high-order levels of self-consciousness, debates that we will address below; (4) *Awareness of awareness:* this definition implies the ability to attribute mental states (theory of mind) to explain or predict others' behaviour. This ability would result from the knowledge of our own mental states; (5) *Self-knowledge:* this last definition includes everything we know about ourselves, not only as a body and a mind but also as a member of a broader social and cultural community. In that sense, self-consciousness thus evolves throughout lifetime.

Zeman thus furnishes five different definitions of self-awareness without explicitly classifying them. Other authors have also defined self-consciousness as a multiple phenomenon but have clearly established a gradation from lowest to highest levels of self-consciousness (see Morin, 2006 for a review). For instance, Fenigstein, Scheier, and Buss (1975) have distinguished "public self-awareness", that is the processing and knowledge of one's own visible attributes (external appearance or behaviours), from "private self-awareness", that is one's knowledge about invisible internal events (physical and physiological sensations, emotions, values, personal aspirations, and so on). The private self-awareness would reflect a superior form of self-awareness by comparison with public self-awareness (see Morin, 2006) because private self-information is more abstract than public self-information[2]. Gallagher (2000) distinguishes two groups of approaches focused on two different aspects of the self, the "minimal self" and the "narrative self". The former corresponds to how is it like to be the immediate subject of one's own experience. It is unextended in time, that is, limited to what is immediately accessible to self-consciousness. The latter is more complex and

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[2] Note however that it might not always be true when internal basic feelings such as hunger or pain, classified as pertaining to private self-awareness, are involved. In these cases, one could imagine more abstract and complex information related to public self-awareness.

extended in time. It refers to a coherent self including a past and a future. In line with this logic of gradation, Newen and Vogeley (2003) have proposed the existence of different levels of self-consciousness as a function of the complexity of self-information that one is able to process. They describe five different levels of self-consciousness related to five different kinds of cognitive abilities entailing increasingly complex forms of representation.

1.3. An integrative summary

Several other authors have developed similar theories that we do not have space to present in full here. Each of these theories has its proper taxonomy but Morin (2006) have integrated them into a more general framework (see Figure 1). An overall view of the existing theories as furnished by Morin allows finding out some similarities and constants about the different levels of self-consciousness that have been described.

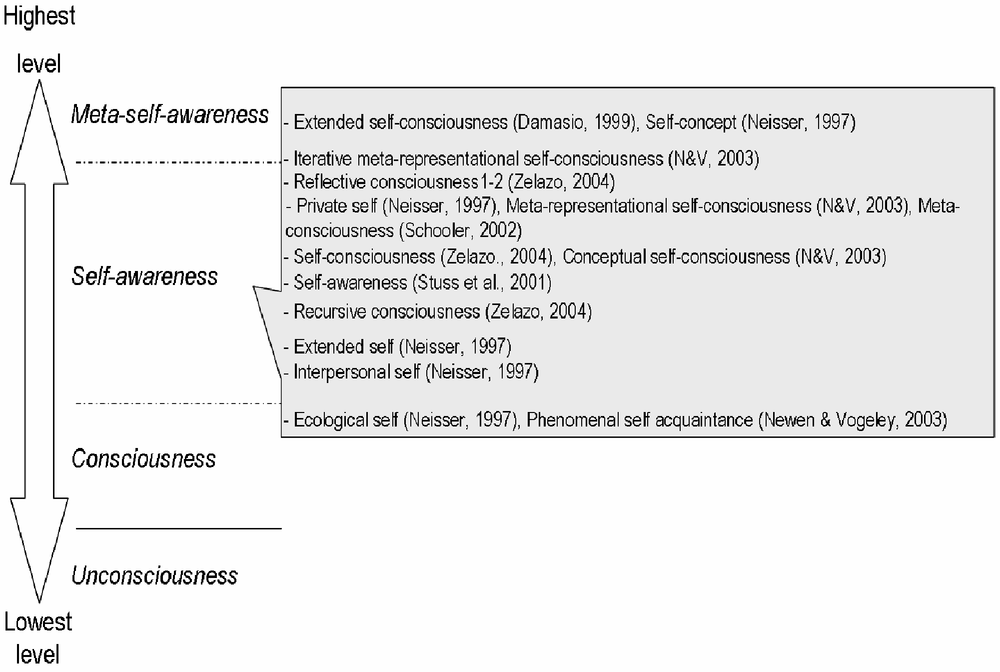

Figure 1. Various levels of self-consciousness as integrated by Morin (Adapted from Morin, 2006).

The different models generally agree about the existence of a basic self-consciousness at a perceptual level. At this stage, one somehow realizes that physical sensations, perceptions and feelings he/she is experiencing are taking place in his/her own body and a self-world differentiation occurs. This capacity is already present before birth in human infants (minimal self, Gallagher, 2000; ecological self, Neisser, 1997; phenomenal self-acquaintance, Newen & Vogeley, 2003; Level 1-differentiation, Rochat, 2003).

Subsequent levels of self-consciousness entail the processing of increasingly conceptual information about oneself. This type of information is not directly available via perceptual experience and a mental representation has to be built (see Morin, 2006). Now, the self-conscious being becomes able to identify him/herself as a unique entity but only from moment to moment. The individual is able to represent him/herself as an object with varying properties and differing from the properties of other objects. He/she can deliberately engage in self-exploration and react to stimulation directed towards him/her (conceptual self-consciousness, Newen & Vogeley, 2003; level 2-situation/level 3-identification, Rochat, 2003; recursive consciousness, Zelazo, 2004).

Afterwards, the self-conscious organism not only understands that he/she is a discrete entity different from others, but also that he/she forms a coherent whole constant throughout time The self-conscious being is able to represent him/herself as taking part in complex events. He/she now starts memorizing episodic events and projecting him/herself into his/her own past or future in relation to a present experience (extended consciousness, Damasio, 1999; narrative self, Dennett, 1991; Gallagher, 2000; extended self, Neisser, 1997; sentential self-consciousness, Newen & Vogeley, 2003; level 3-identification/level 4-permanence, Rochat, 2003; self-consciousness, Zelazo, 2004).

A further stage is achieved when the self-conscious being acquires an even more conceptual knowledge about him/herself and concomitantly about others (his/her own or their will, goals, personality, feelings, behaviours, reactions and so on). He/she acquires a theory of mind. He/she has more and more abstract knowledge about people and situates him/herself in a broader social context (private self, Neisser, 1997; meta-representational self-consciousness, Newen & Vogeley, 2003; reflective consciousness 1-2, Zelazo, 2004).

The ultimate stage seems to be reached when the self-conscious being can reflect on his/her own self-consciousness. He/she can take into account his/her own and others' knowledge about him/herself to adapt his/her behaviour (self-concept, Neisser, 1997; iterative meta-representational self-consciousness, Newen & Vogeley, 2003; level 5-meta self-awareness, Rochat, 2003; reflective consciousness 1-2, Zelazo, 2004).

All these levels seem to develop chronologically during human ontogenesis (see Newen & Vogeley, 2003; Rochat, 2003; Zelazo, 2004) and the highest levels cannot be achieved without first possessing the lowest. We can assume that once one has attained the highest levels of self-consciousness, he/she can still develop and improve his/her knowledge and the complexity of representations about the lower levels. Self-consciousness would be a dynamic process oscillating between all these different levels and one would not show the most complex form of self-consciousness at every moment (Rochat, 2003).

Now that we have described the different aspects that the term "self-consciousness" can refer to, we will explore the different fields in which it has been investigated through self-referential stimuli. In the next sections, we will in most cases remain focused on visual self-referential stimuli defining one's own appearance. Our central question will be whether presentation of self-referential stimuli and investigation of their processing can be an efficient way to understand the functions and the mechanisms of self-consciousness.

2. Comparative perspective

Are we, human beings, alone with our self-consciousness? If for Descartes, animals were conscious automata just able to perceive and feel external inputs but without knowing it (Smith, 1998), the question of animal self-consciousness is nowadays actually still a subject of debate. For Descartes, human beings differed from the rest of the animal kingdom in their capacity to know that they know, in other words, self-consciousness (Smith, 1998). Since Darwin however (see Dawkins, 2006), there is a consensus that non-human animals (at least mammals and birds) are conscious, at least in the sense of sentience. It seems obvious that they are able to perceive external stimuli as well as physical sensations (see

Zeman, 2001). But are they able to go a step further and think about their experience? Will they suffer beyond the direct sensation of pain or distress? This question is important by itself and also from an ethical point of view with regard to animal welfare for instance (Morton, 2000).

Since animals do not possess a direct way (i.e., a language similar to ours) to communicate about their experience or the way it is to be them, researchers have developed different methods to answer this question of animal self-consciousness. We will focus on those involving the presentation of self-referential stimuli, and more precisely in the visual modality. The most extensively used method is probably the “mirror” or “mark test” (for reviews see Anderson & Gallup, 1999; Bard, Todd, Bernier, Love, & Leavens, 2004; Schilhab, 2004) assessing the mirror self-recognition (MSR). This test has above all involved chimpanzees and other primates. It has more recently been adapted for the investigation of cetaceans (Delfour & Marten, 2001; Reiss & Marino, 2001) and elephants (Plotnik, de Waal, & Reiss, 2006; Povinelli, 1989).

2.1. Self-recognition in primates

When exposed to mirror, most animals with sufficient visual abilities will react as if they were facing a conspecific. After a while however, some of them may start to show mirror-guided self-directed behaviours (see Gallup, 1968, 1970). Gallup (1970) designed the famous mark test in order to create an empirical tool that would be an objective measure of such behaviours. In his initial study, four chimpanzees (*Pan troglodytes*) were first isolated in a cage for two days. Afterwards, a mirror was added and animals were exposed to it for a total of approximately 80 hours. During this period, as observed previously, chimpanzees first displayed social responses towards the mirror, but these responses gradually turned into self-directed responses via the mirror (i.e., for instance inspection of body areas otherwise invisible, making faces and so on) over a few days. Then, to assess whether these self-directed behaviours reflected self-recognition, the animals were anesthetized and while they were unconscious their eyebrow and the opposite ear were marked with an odourless and tactile-free dye. When the animals recovered from the anaesthesia (around four hours after having been marked), they were observed to count the number of spontaneous movements directed towards the marks while the mirror was absent. The mirror was finally reintroduced and the animals were observed in the same manner. Results showed that the number of responses towards the marks dramatically increased after the mirror had been reintroduced. The viewing time also increased by comparison with the baseline and visual inspection of the fingers that had touched the marked areas was observed. In addition, two additional naïve (i.e., with no mirror experience) chimpanzees were also marked while sedated and then introduced with a mirror. Contrary to the others, these subjects did not make any mark-directed responses, suggesting, according to Gallup that the others chimpanzees had learned to recognize themselves during the period of exposition to the mirror.

Gallup (1970) repeated this procedure with macaques (see also Gallup, 1977), rhesus monkeys and cynomolgus monkeys but they failed to manifest any self-directed response and kept responding socially to their reflection. Gallup concluded that his data was the first demonstration of a self-concept in non-humans and that this ability for self-recognition, which required an advanced form of intellect, might be restricted to humans and great apes. These results have been replicated (Gallup et al., 1995; Kitchen, Denton, & Brent, 1996; Lin, Bard, & Anderson, 1992; Suarez & Gallup 1981) and extended to orang-utans (Suarez & Gallup, 1981) and bonobos (Westergaard & Hyatt, 1994). Attempts of extension to gorillas have been less clear as they were sometimes successful (Swartz & Evans, 1994) and sometimes not (Ledbetter & Basen, 1982). In line with Gallup's claim, all the studies conducted on prosimians or monkeys had resulted in negative outcomes (for a review, see Anderson & Gallup, 1999; Gallup, Anderson, & Shillito, 2002; but see Hauser, Kralik, Botto-Mahan, Garrett, & Oser, 1995; or de Waal, Dindo, Freeman, & Hall, 2005 for a recent study with capuchin monkeys showing that they might discriminate self and others in the mirror).

Later, it has been shown that chimpanzees capable of MSR can also recognize themselves in distorted mirrors and thus use movement cues in addition to usual visual cues to identify the reflection as themselves (Kitchen et al., 1996). According to Kitchen and colleagues, this indicates that chimpanzees possess abstractive abilities that allow recognizing themselves even on deformed images. A recent study also report cases (2 out of 10) of chimpanzees able to recognize themselves (as attested by self-exploration behaviours) on live video images (Hirata, 2007). However, other studies have shown that MSR is not so systematic in chimpanzees, some individual chimpanzees remaining unable to pass the mark test (de Veer, Gallup, Theall, van den Bos, & Povinelli, 2003 ; Kitchen et al., 1996; Swartz & Evans, 1991), and MSR being age dependent (Bard et al., 2006; de Veer, Gallup, Theall, van den Bos, & Povinelli, 2003; Lin, Bard, & Anderson, 1992; Povinelli, Rulf, Landau, & Bierschwale, 1993).

2.2. MSR in other animals?

Even if the mark test procedure was not necessarily used, the reactions of a wide range of animals to their mirror-image have actually been examined. These studies have revealed that most animals, including fish, dogs, cats, sea lions, monkeys (for a review, see Gallup, 1968), marmots (Svendsen & Armitage, 1973) and birds (Diamond & Bond, 1989), interact with their reflection as if they were in presence of another animal.

Some authors, however, have made efforts trying to adapt the mark test procedure to assess self-recognition in non-primates. Elephants, being reputed for their intelligence and given the dexterity of their trunk to explore their environment and their own body, appeared as ideal candidates (Povinelli, 1989). In the first attempt reported, two Asian elephants (*Elephas maximus*) were tested but failed to show any sign of self-recognition. Even if animals show substantial interest in the mirror after its introduction, this interest quickly declined over of few days. They did not “pass” the mark test as they never touched the marked area while facing the mirror. One of them nevertheless inspected marks on the other one, indicating that the marks were visible to them. Despite their lack of self-recognition, both animals appeared able to use the mirror to find otherwise invisible food. This indicates that the failure to pass the mark test found in these elephants (and also in other animals) is not due to an inability to process information related to spatially displaced items (Povinelli, 1989). More recently, however, one case of MSR has been reported in one elephant (Plotnik et al., 2006). In this second study, three Asian elephants were tested. Unlike other animals, they did not respond socially to their reflection when the mirror was first introduced (but presumably all of them had prior mirror experience in the zoo where they live). All of them nonetheless produced self-directed and mirror-testing behaviours (for instance they brought food and ate in front of the mirror, what they did not do at this place in the absence of the mirror) and tended to use the mirror to explore their own body. Each of them was marked on the right side of its head, and a similar but invisible sham-mark was applied on the left side. Only one out of the three elephants passed the mark test (i.e., touched the visible mark more often than the sham mark while or just after facing the mirror). Attempts with other elephants and next attempts with this same elephant were unfruitful. The authors concluded that contrary to primates that frequently autogroom and inspect specific parts of their body in detail, elephants might lack concern about their cleanliness and appearance.

Similar experiments have recently been conducted with cetaceans. Due to their absence of hands, the procedure had have been adjusted and the interpretation of the animals' behaviour is maybe even more complicated than with primates (Delfour & Marten, 2001). In one of these studies (Reiss & Marino, 2001), two dolphins were marked on different body parts that were invisible without the help of a mirror. They were also sham-marked or unmarked at two other moments. Their behaviour was compared in the presence and in the absence of mirrors inside the pool. Results showed that dolphins spent more time at the mirror location when they had been marked than in other conditions and also when the mirror was present than covered or absent. They used the mirror to explore the marks and went faster toward the mirror location when they had been manipulated (marked or sham-marked) than when they had not been touched. Three killer whales (*Orcinus orca*)'s behaviour when facing mirror has also been investigated (Delfour & Marten, 2001). While facing the mirror, they had specific head movements, they open their mouth, showed their tongue and play with a piece of fish in mouth longer than in the absence of mirror. One of them rubbed her head against the wall several times after having been marked and inspected her reflection in the mirror. Similar behaviours were observed in false killer whales but not in Californian sea lions that displayed social behaviours.

In conclusion, these studies reviewed so far suggest that MSR might not be due to specificities shared by humans and great apes but rather that this ability might result from more general factors such as sufficient cognitive abilities and high encephalization (Reiss & Marino, 2001). However, a study with pigeons by Epstein, Lanza, and Skinner (1981) could at first sight question this view. In this study, pigeons were trained to peck at dots place on different locations of their body by reinforcement. Then a mirror was introduced in front of the cage and pigeons were further trained to peck at blue dots placed inside the cage. Then, a dot that could only be seen with the mirror was presented and pigeons received food if they peck at it. Afterwards, the same blue dot was placed on their chest and hidden from their direct view with a bib. Results showed that the number of pecks at this dot dramatically increased when the mirror was uncovered by comparison with a situation where it was covered. This study thus indicates that pigeons have the ability to explore their own body with mirrors. However, comparisons with traditional mark test studies should be cautious as the conditions were very different here (see Schilhab, 2004). Remember that the mark test has been designed to investigate further pre-existing spontaneous self-directed behaviours with mirrors (see Anderson & Gallup, 1997, 1999). These spontaneous behaviours were inexistent in pigeons. Moreover, this reinforcement procedure involved food reward which is never the case in the classical mark test. As stated by Schilhab (2004, p. 116), “the study on pigeons was deemed incomparable and with no implications for investigations of chimpanzees”.

This section illustrates that the evidence so far for MSR in non-primates is actually quite limited. Further inquiries are probably necessary to get more convincing data and stronger support for the presence or absence of this ability among the animal kingdom. The question thus arises of what this test really measures and how results should be interpreted. Does a failure to pass the mark test automatically exclude the possibility of self-consciousness, in other words is it conceivable for some organism to be self-conscious while being unable to grasp the meaning of a mirror? On the contrary, does passing the mark test really constitute an evidence of self-consciousness? These questions have been the subject of many debates in the literature.

2.3. Methodological and theoretical debates around the mark test

According to Gallup and his colleagues, « the ability to correctly identify the source of the reflection as oneself – to become the object of one’s own attention – requires a cognitive category of self » (Anderson & Gallup, 1999, p. 180). They go further and claim that MSR is an indicator of self-awareness (Gallup, Anderson, & Shillito, 2002). Their reasoning is that the capacity to correctly attribute the source of the mirror image to oneself requires a preexisting self-concept involving three components: senses of identity, of personal agency and of identity. As a result of its experience with its own mental states, the organism capable of MSR would in turn be able to make inferences about others' mental states (i.e., theory of mind) (Gallup, 1998; Gallup, Anderson, & Shillito, 2002). On the contrary, species that do not manifest MSR should also be unable to show introspectively based social strategies such as empathy, deception and so on (Gallup, Anderson, & Shillito, 2002).

This theory has been seriously questioned by others, either on the basis of methodological flaws identified in the mark test (Heyes, 1994), or on the basis of alternative interpretations of results to the mark test (Heyes, 1994; Mitchell, 1993, 1997). We will briefly expose some of the most prevailing criticisms (for a review, see Anderson & Gallup, 1999; Schilhab, 2004; interested people will also find these arguments developed in detail in a whole issue of New Ideas in Psychology, Vol.11, Issue 3 devoted to this topic in 1993).

1) Missing baseline: The mirror could just elicit social behaviour, while the gradual increase of self-directed behaviour in front of the mirror could only reflect a return to the normal level of auto-grooming after the chimpanzee gets habituated to the presence of the mirror. A baseline taking into account the number of self-directed behaviours (in general but also at the future location of the marks) prior the introduction of the mirror is missing to refute this interpretation (Heyes, 1994).

2) Anaesthesia hypothesis: the increase of mark-directed behaviour could just be an artefact produced by the anaesthetic (Heyes, 1994). Moreover, the argument that the control subjects (i.e., without prior mirror experience) that had also been anaesthetised did not engage in self-directed behaviour when facing the mirror is not an evidence that the other chimpanzees had learned to recognize themselves. It is actually perfectly logic that being exposed for the first time to a mirror, they were socially responding to their reflection (Heyes, 1994). However, some studies obtaining similar results as Gallup's have been carried out without anaesthesia (Lin et al., 1992) but they did not use the same measures (i.e., they compare the number of mark-touching while looking toward or away from the mirror, and not in the absence of mirror) than in the classic mark test (Heyes, 1994).

3) Viewing time: the observation that animals spend more time facing the mirror when marked than when unmarked does not prove that they understand that the mark is on their own body. Indeed, a viewing time effect can be found in animals that do not pass the test (Heyes, 1994; Mitchell, 1993). In line with this claim, it has been shown that children viewing a mark on their mother's nose sometimes wipe their unmarked own nose (Lewis & Brooks-Gunn, 1979). This renders the interpretation of behaviour in front of the mirror quite difficult (Schilhab, 2004).

4) Nonmentalistic hypothesis: According to Epstein et al. (1981), their study with pigeons illustrates that a self-concept is not necessary to pass the mark test (see also Heyes, 1994; Mitchell, 1993, 1997). However, as we already mentioned, this study involved reinforcement and food reward and therefore, these results obtained with pigeons are hardly comparable with those obtained in the usual paradigm (see Schilhab, 2004). Nonetheless, it is still possible that MSR just imply a very basic sense of self, just allowing a self-world differentiation, and not an elaborated self as can be found in humans (Heyes, 1994; Mitchell, 1993, 1997). Moreover, the links between MSR and theory of mind appear quite shaky to some authors. Indeed, accurate MSR can be found in cases of problematic mental states attribution in autistic children for instance (Heyes, 1994; Mitchell, 1997). It thus seems that a "strong" interpretation of MSR (as advocated by Gallup and colleagues) contrasts with a nonmentalistic more restrictive, "weak", approach in the literature (see Schilhab, 2004). This point demonstrates the pertinence of a clear definition of self-consciousness and the importance to keep in mind at which level of investigation one is situated as stated in the first section of the present chapter.

5) Kinesthetic-visual matching: MSR is possible through two capacities, kinesthetic-visual matching, that is, the ability to detect contingencies between one's own actions and the mirror image; and understanding mirror correspondence (Mitchell, 1993, 1997). Therefore, "recognizing oneself in the mirror does not require that one is aware of all aspects of self or that one monitors one's mental states" (Mitchell, 1997, p. 26). This hypothesis is actually consistent with data showing that chimpanzees can recognize themselves via distorted mirrors (Kitchen et al., 1996).

6) Problems of false negatives: in contrast with the points elaborated above as regard with misinterpretation of success to the mark test, a last issue concerns the cases in which the inherent characteristics of the mark test would not be suited to detect an existing ability of self-recognition in some species. As Schilhab (2004, p. 121) notes, “deficiencies solely in eyesight could then be responsible for the failure in passing the mark test”. In the same order of idea, it has been argued that some monkeys could fail the mark test because they could avoid eye-contact that is a sign of aggression to them. This would prevent them from getting the opportunity to learn that they are the source of the mirror-image (Hauser et al., 1995).

2.4. Conclusion

The selected review of comparative studies presented above shows that visual presentation of self-referential stimuli can be useful to investigate self-consciousness in animals. However, as we have seen, the most used paradigm in this realm is still subject to debates as regard with the interpretation of the information it can bring. These debates highlight the importance of having an operational definition of self-consciousness to interpret data. As Morin has very pertinently noted, the question should not be to know whether animals that do recognize in the mirror are really self-aware but rather “what *kind* of self-awareness does self-recognition imply?” (Morin, 2006, p. 367).

The mark test is maybe the only test researchers have at present to study self-consciousness in animals. However, they should keep in mind that if this test really assesses self-consciousness, it is probably just a particular component of self-consciousness. Indeed, MSR could be explained via relatively simple processes involving a basic self-concept. We are thus still far from resolving the riddle of self-consciousness in the animal kingdom. If anything, the mark test is a detector of self-consciousness but it might be only of little help to understand further the mechanisms of self-consciousness. The main outcome of its use is that MSR seems restricted to organisms otherwise possessing high cognitive abilities and a highly developed brain. The possibility remains that the mark test may miss instances of self-recognition/self-awareness in some organisms. Researchers should ensure that the test fits the physical, physiological, behavioural and motivational characteristics of the organism under investigation and be wary of biases resulting from an over anthropomorphist point of view (Schilhab, 2004). For Greenfield and Collins (2005), there is no phylogenetic gap between the physiology of animals' brains and ours. Therefore, "consciousness is most likely to be a continuously variable property of the brain, in both phylogenetic and ontogenetic terms (…). Consciousness will grow as brains grow" (p. 586). It might be the same about self-consciousness. Maybe the best way to progress in this field is nonetheless to keep in mind, as Dawkins says (2006, p. 9), that "animals are not little furry or feathered humans looking at the world through human eyes and science can help us to understand what it is like to look through those different eyes. Real respect for animals will come when we see them as sentient beings in their own right, with their own views and opinions, their own likes and dislikes."

3. Developmental perspective

Visual presentation of self-referential stimuli has also been used with human children trying to understand the ontogeny of self-recognition and ultimately of self-consciousness. Interestingly, Amsterdam (1972) has developed almost at the same time as Gallup a similar paradigm to the mark test to investigate self-recognition in human infants (for a comparison of the test in primates and in human infants, see Bard et al., 2006). In several aspects, this test has been judged less rigorous than the one used in comparative studies (see Bard et al., 2006). The differences between the mark tests used in the two approaches are summarized in Table 2 for information but will not be developed here. Moreover, we will also not address the debate surrounding this test since it is similar to that found in the comparative perspective. Here we will focus on the contribution of the mark test to the understanding of the ontogeny of self-recognition and afterwards will present the new developments brought by other paradigms.

3.1. The mark test in human infants

MSR in human infants does not simply appear one day. It develops following systematic successive stages (Bertenthal & Fischer, 1978; Courage & Howe, 2002), up to the explicit recognition from around 18 months of age (Amsterdam, 1972; Nielsen, Dissanayake, & Kashima, 2003). Interestingly, the first stages of MRS in the infant humans are similar to those observed in the infant chimpanzees (Bard et al., 2006; Lin et al., 1992).

The Mark test and Its Application: Amsterdam's and Gallup's Methods and Rationale

Amsterdam (1972)	*Gallup (1970)*
The Mark and its application	
Spot of rouge	Alcohol-soluble dye (Rhodamine B-base)
Applied (covertly?) by mother	Applied while unconscious
Place alongside nose	Placed on brow ridge and opposite ear
In one location	In two nonvisible locations
Rationale and implications	
Seminaturalistic laboratory	Highly controlled laboratory
Mimic everyday acitivity	Controlled discovery of the mark
Minimize distress	Dye cannot be felt or smelled
High ecological validity	Marked under anesthesia
Objective behaviour	Objective behaviour
Locate mark on face = MSR	Locate mark on face = MSR
One spot-generalized response	Two spots-touch specific places

Note. MSR – mirror self-recognition.

Table 2. Summary of the differences between the mark tests as used in developmental (Amsterdam, 1972) and comparative (Gallup, 1970) approaches (From Bard et al., 2006).

The young infants do not understand directly the correspondence between the world and the reflected world nor are they aware that they are the source of the reflected image. At first, from 3 months of age the young infants are attentive and positive towards their own reflection (see Courage & Howe, 2002). This interest towards their own image might be an important factor in the development of MSR (Nielsen et al., 2003). Typically around 8 months of age the infants become aware of the contingencies between their own movements and the reflection (Courage & Howe, 2002). They then explore the mirror tactically (Bertenthal & Fischer, 1978) and use these contingencies to play (Courage & Howe, 2002). Between 10 and 18 months, the infants explore further these contingencies and compare their hands movements to the reflected images (Zazzo, 1993). The infants start to understand the correspondence between the world and its reflection in the mirror as they can turn back towards objects placed above or behind them (Bertenthal & Fischer, 1978).

The explicit recognition – as attested by passing the mark test (i.e., objectivised by movements directed towards a rouge mark on the nose) – appears between 18 and 24 months (Amsterdam, 1972; Bertenthal & Fischer, 1978; Courage & Howe, 2002; Zazzo, 1993). It is at this period that the infants show reactions of embarrassment, perplexity or avoidance in front of the mirror (Amsterdam, 1972; Courage & Howe, 2002; Zazzo, 1993). These reactions could be due to the ambiguity resulting from an incomplete understanding of the mirror (Courage & Howe, 2002; Zazzo, 1993) but they are also the first signs of children awareness of their appearance to other people (Rochat, 2003). In fact, it seems that children can recognize their own reflection before fully understanding the optical properties of mirrors. Children up to 5 years old can bypass the mirror trying to reach an object actually situated behind them (Courage & Howe, 2002; Zazzo, 1993).

Finally, between 22 and 24 months, the children can correctly label their own reflection (Bertenthal & Fischer, 1978; Courage & Howe, 2002). Note however that children between 1 and 2 years can use the personal pronoun “me” or their own first name when they see a video of themselves as well as when they see a video of a peer. This illustrates that cues of self-recognition must be carefully chosen (Johnson, 1983).

Passing the mark test and correctly naming one’s own reflection are probably crucial indices of the construction of a sense of self and of one’s own identity during infancy. However, MSR is just a snapshot of one of all the abilities reflecting the construction of a sense of self and different levels of self-consciousness (see Rochat, 2003). The MSR would be based on perceptual cues and on early abilities to discriminate between oneself and the others (Legerstee, Anderson, & Schaffer, 1998) reflecting lower levels of self-consciousness. Moreover, other stages must be reached after MSR before getting a more elaborated (i.e., coherent and extended in time) sense of self as described in the first section of this chapter. Other techniques and paradigms than the mark test have been used to investigate more precisely these other stages of self-recognition and corresponding levels of self-consciousness.

3.2. Other levels of self-consciousness

Infants are capable of discriminating between themselves and others and develop a (implicit) sense of self long before explicitly recognizing themselves in the mirror (Rochat & Striano, 2000). They are born with perceptual means to do so (Rochat, 1998). At least from 2 months of age they engage in self-exploration and pick up unique visual and proprioceptive contingencies specific to their own body (Rochat, 1998; Rochat & Striano, 2000). Video experiments have shown that at three months of age, infants show some abilities to discriminate their own body or face from those of other persons (see Courage & Howe, 2002) and to discriminate congruent from incongruent views of their legs (Rochat, 1998) that manifest through looking preference. From 4-5 months of life, infants prefer looking at a video of a peer or a doll (Legerstee et al., 1998) or of an adult imitating them (Rochat & Striano, 2002) than at a video of their own face. This suggests a preference for novelty and therefore some familiarity with their own face. This familiarity would result from prior exposition to mirrors. Around 9 months, they perceived another person presented on a video as a social partner more than themselves (Rochat & Striano, 2002). Around 18 months, appearance of MSR typically coincides with a looking preference towards their own face by comparison with a peer’s face (Nielsen et al., 2003).

This early sense of self (labelled ecological self, Rochat, 1998) which is present before explicit self-recognition is thus determined by direct perception and action. Early discrimination abilities constitute a perceptual basis necessary for the emergence of self-recognition and to the elaboration of a higher level sense of self (Rochat & Striano, 2002). This perceptual basis apparently emerges from the processing of dynamic information of movements, of intermodal invariant information specifying the own body and also of facial features themselves (Legerstee et al., 1998; Rochat, 1998; Rochat & Striano, 2002).

After the MSR is reached, one or two additional years will pass before children can develop a stable and spatio-temporal contingent independent representation of themselves. Studies adapted from the mark test have used online versus differed video sequences to investigate this topic (Miyazaki & Hiraki, 2006; Povinelli, Landau, & Perilloux, 1996; Povinelli & Simon, 1998; Suddendorf, 1999). It appears that video self-recognition is more difficult than mirror self-recognition as it develops about a year after mirror self-recognition (Suddendorf, Simcock, & Nielsen, 2007). Also, young children recognize themselves more easily with a live than with a delayed feedback. For instance, when a sticker has covertly been placed on children's head while they were playing and videotaped, most 3-years-old children realize the presence of the sticker on their head and remove it if the tape is played live but do not if the tape is presented with a three minutes delay (Povinelli et al., 1996). At this age, children will also not remove the sticker if they are shown Polaroid pictures taken during and after the placement of the sticker. However, these same children can correctly label the video or Polaroid images and remove the sticker when facing a mirror. On the contrary, 4-years-old children can infer the presence of the sticker on their head when seeing delayed video feedback.

All these studies show the existence of a developmental evolution of self-recognition going from lowest levels entailing a basic self-other differentiation to highest levels implying a more elaborated self-concept extended in time. Rochat (2003; see also Section 1 of the present chapter) has identified five steps in this progression, each corresponding to different levels of self-consciousness. At Level 1 (Differentiation) the infants differentiate themselves from the world. They possess a differentiated self. At Level 2 (Situation), infants go beyond this awareness and perform self-exploration. They express a situated self. Then at Level 3 (Identification) they can recognize in the mirror and refer explicitly to the self. This is the manifestation of a conceptual self. At Level 4 (Permanence), they can identify themselves independently of the temporal simultaneity and spatial coincidence provided by mirrors. This is the expression of a permanent self. At a last level (Level 5, Meta self awareness) that we did not tackle here yet, individuals can also represent themselves from a third-person perspective.

3.3. Context of self-recognition

Visual self-recognition is of course not the only ability allowing the development of self-consciousness. It emerges along with other important abilities such as language (Herschkowitz, 2000), memorisation of episodic events (Courage & Howe, 2002; Herschkowitz, 2000), object permanence (Bertenthal & Fischer, 1978), auditory self-recognition (i.e., investigated by the presentation of one's own voice, Legerstee et al., 1998) or synchronic imitation (Asendorpf & Baudonnière, 1993). All these different abilities will participate in different aspects of self-consciousness. They will be unified to form a coherent self-concept long after two years old in consideration of increasing interconnections between both cerebral hemispheres and cortical and subcortical structures increasing between 1 and 2 years old (Herschkowitz, 2000).

Moreover, the fact that results of video self-recognition task and results on another video task (i.e., locate an object in space) highly correlates might shed doubt on the assumption that "delayed video mark test" assesses development of self-consciousness. Indeed, children's difficulties with videos are not specific to self-recognition tasks (Suddendorf, 1999; see also Suddendorf et al., 2007).

3.4. Conclusion

The use of visual self-referential stimuli appears to be in most cases a satisfying index of the emergence of self-consciousness in humans. This is mostly of great help to test infants and children before they can use language unequivocally to express their self-consciousness (Gouin-Decarie, Pouliot, & Poulin-Dubois, 1983). The mirror-mark test, and more recently developed video-mark test, remains the subject of some debates and interpretation of the results should still be executed with caution (see for instance Mitchell, 1993; Suddendorf, 1999). Moreover, it has often been used in less controlled (but more ecological and less distressful) settings than in comparative studies (see Bard et al., 2006). However, developmental researchers, at least when studying normal infants, probably conduct their studies with the a priori that their subjects are already or will be (once again depending of the definition of self-consciousness one adopts) self-conscious organisms. This might explain the differences between this approach and the comparative approach. In the latter, researchers try to detect self-consciousness in organisms that can not (and will never) directly communicate it. Therefore, the danger is that they might adopt all-or-nothing point of views about self-consciousness. On the contrary, the developmental approach intrinsically focuses on the moment at which different abilities develop. This is probably the reason why researchers in this field seem in agreement with a more gradual vision of self-consciousness and why developmental studies have abundantly contributed to theories of self-consciousness (see for instance Newen & Vogeley, 2003; Rochat, 2003; Zelazo, 2004). Of course, the presentation of visual self-referential stimuli allows the investigation of only a little portion (i.e., visual self-recognition) of all the aspects of self-consciousness occurring during the human development. Once the language is mastered, other aspects of self-consciousness can in turn be more easily investigated.

4. A way to find the self in the brain?

Self-referential stimuli of various kinds (own face, own name, own voice, self-descriptive adjectives or sentences, one's own personality traits, etc) and various tasks involving self-reference (perspective taking, self-agency, episodic memory retrieval, evaluative judgments, decisions about food preference, etc) have been extensively used these last ten years (for reviews, see Northoff & Bermpohl, 2004; Northoff et al., 2006; see also Sugiura et al., 2005 for a review about visual self-recognition) with the more or less explicit aim of finding out the neural circuitry underlying self or self-consciousness. The title of papers by Craik and colleagues in 1999, "In search of the self: A positron emission tomography study", or more recently in 2005 by Feinberg and Keenan, "Where in the brain is the self?" on this topic are unequivocal. We will not develop the results of these studies in detail here; we will do so in the next chapter. In the present section, the rationale put behind these studies and the conclusion drawn from their results will be briefly examined.

4.1. Rationale of neurocognitive studies

Adults or sometimes children's brain activity have been recorded with neuroimaging and electrophysiological techniques (i.e., positron emission tomography – PET, functional magnetic resonance imaging – fMRI, event-related potential – ERP, are the most commonly encountered) while they were engaged in self-referential processing of various kind (see Gusnard, 2005 for a review and a reminder about functional neuroimaging principles). Typically, this activity has been compared to that elicited by the processing of non-self-referential stimuli. Another range of techniques has been occasionally used to temporarily disable specific brain regions (see Keenan, Nelson, O'Connor, & Pascual-Leone, 2001; Théoret et al., 2004; Uddin, Molnar-Szakacs, Zaidel, & Iacobini, 2006), in other words to create virtual lesions (i.e., transcranial magnetic stimulation – TMS), or to disable each cerebral hemisphere one at a time (intracarotid sodium amobarbital procedure – ISAP or WADA test). Deleterious effects of these manipulations on the realisation of tasks involving self-referential stimuli were then examined. Finally, differences of cerebral activity patterns between healthy subjects and subjects suffering from disorders implying alterations of some aspects of the self (i.e., schizophrenia, delusional misidentification syndrome, dementia, for example) have also been examined in order to understand the way in which the self is created by the brain (see Feinberg & Keenan, 2005; see also Section 5 of the present chapter for more details about this last point).

Just as Kriegel (2007) has recently noted about studies investigating neural correlates of consciousness (NCC), two hypotheses are encountered in the literature investigating neural correlates of self-consciousness: descriptive and explanatory hypotheses. In the same way as with NCC, descriptive studies aim at localising the cerebral structures underlying various aspects of self-consciousness. The explanatory view makes hypothesis about why these specific regions are involved in self-consciousness.

4.2. Finding converging evidence?

Northoff and Bermpohl (2004)'s approach is certainly of the second type (i.e., explanatory). They have gathered various imaging studies exploring self-processing and integrated their findings into a neuroanatomical explanatory model. First of all, they have noted that cortical midline structures (CMS) have been found to be implicated in various tasks going from perspective taking to self-face recognition. They claim that specific regions of the CMS are implied in different self-related subprocesses (see Figure 2).

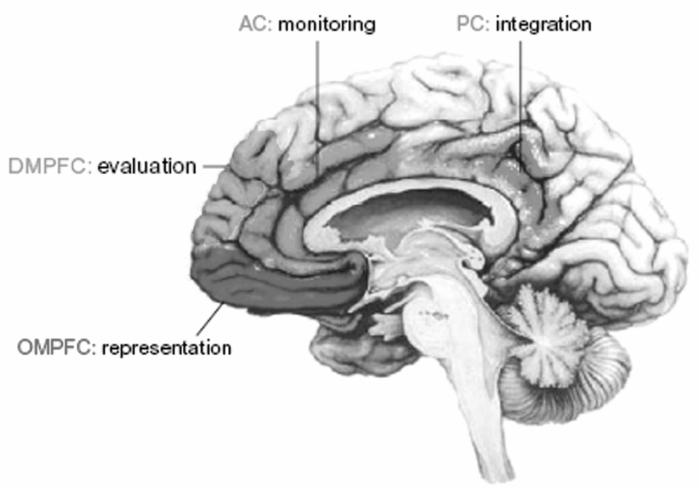

Figure 2. Subprocesses of self-referential processing and their associated regions - OMPFC, orbitomedial prefrontal cortex; DMPFC, dorsolateral prefrontal cortex; AC, anterior congulate cortex; PC, posterior cingulated cortex (from Northoff & Bermphol, 2004).

They identify four self-related functions: representation and evaluation of self-referential stimuli, a monitoring function associated with a preferential processing of self-related stimuli independently of the task or of the sensory modality, and finally an integration function of self-related information in the context of one's own person. These four functions would imply most frontal to more posterior CMS. A similar view that different regions of the CMS are commonly activated during various self-related tasks is advocated in a more recent paper from the same group (Northoff et al., 2006). They have done a meta-analysis with various studies implying self-processing and have performed cluster and factor analyses. They have found three (ventral, dorsal and posterior) clusters within the CMS but none of these were associated with a particular domain or modality (they had included studies implying visual, auditive, or mental tasks/presentations).

4.3. Potential issues

Beyond the limitations inherent to each technique (relative spatial and temporal resolution of fMRI and ERPs for instance) used to identify the neural correlates of self-consciousness, some fundamental issues should be considered when investigating neural correlates of self-consciousness.

The first one concerns the tendency to presuppose that some specific self-referential processing is equivalent to self-consciousness. In this view, cerebral correlates of this specific processing are identified as the cerebral correlates of the self or of self-consciousness whereas they are only demonstrated in really specific self-related tasks. This issue has been raised by Morin (2002, 2007) about Keenan and his collaborators' work on visual self-recognition (see Keenan, et al., 2001; Keenan, Rubio, Racioppi, Johnson, & Barnacz, 2005; Keenan, Wheeler, Gallup, & Pascual-Leone, 2000; Platek, Keenan, Gallup, & Mohamed, 2004). According to Morin, Keenan and colleagues claim that self-recognition is equivalent to self-awareness and that since self-recognition mainly involves activity in the right hemisphere (specifically the prefrontal lobe), self-awareness is underlain by right hemispheric activity. Morin's main objection is that access to one's own thought or cognitive self-knowledge is not necessary for self-recognition to occur (see Section 2.3. of the present chapter for a similar argument). Rather, self-recognition could only be based on a (lower level) kinaesthetic self-knowledge. It thus appears dangerous to draw very general conclusions on the basis of one single (or even several few) self-related ability.

The opposite problematic tendency might consist in assembling data obtained with various tasks each involving different kinds of self-processing and self-referential stimuli presented in different modalities (beyond the technical differences existing between each study) to determine the brain areas involved in self-consciousness and to elaborate a general theory of self-consciousness. This approach might be misleading because one cerebral area involved in one specific self-related ability will not necessarily be involved in another self-related ability. Taking all the previously identified brain areas into account in one single model would probably show that self-consciousness is entailed by (nearly) the whole brain (see Legrand, 2003, for a similar view).

Finally, as already mentioned above, neural correlates of self-referential processing have been studied with various kinds of self-referential stimuli and tasks. These tasks actually entailed either a perceptual processing of self-referential stimuli (e.g., own name presented visually or auditorily, own face, own voice), or a more conceptual and mental processing (e.g. for example subjects are instructed to think intensely on how they would describe their own personality traits and physical appearance, see Kjaer, Nowak, & Lou, 2002; or to mentally identify a person depicted in a picture, see Platek, Keenan, et al., 2004). In that latter case resides the last obvious potential issue. Indeed, subjects are at best presented with equivalent stimuli (a picture of their own face) but this is not even the case when the task is purely mental. Since no behavioural response has to be made, little control on what the subject is actually doing during the brain activity recording is possible. Thus it seems extremely difficult to draw strict conclusions from such tasks.

4.4. Conclusion

The neurocognitive investigation of self-consciousness is very recent and still in its infancy. This section once again illustrates the importance of having a clear definition of self-consciousness and above all to be aware of the aspect of self-consciousness put under investigation. Indeed, all the studies existing to date have in fact examined at best only few aspects of self and self-consciousness at the same time. Conclusions drawn from these studies should therefore stay humble. A paradigm allowing the study of the neural correlates of the self in its entirety, i.e. simultaneously involving all the aspects of self or at least various aspects of self in comparable conditions, remains to be built. A work of integration such as started by Northoff and his colleagues (Northoff & Bermpohl, 2004; Northoff et al., 2006) is probably necessary. However, people should ensure that the results they use are generalisable in order to build accurate models of self-consciousness.

In this section, we mainly tackled the neural correlates of self-consciousness in healthy subjects. The next section will focus on the use of self-referential stimuli in populations suffering from various alterations of self-consciousness.

5. The cases of altered self-consciousness

Self-referential stimuli (particularly one's own name and one's own face) has been used with a wide range of subjects suffering of various "alterations of self-consciousness". As it is often the case with pathological population, research has been carried out according to two (non mutually-exclusive) general approaches. On the one hand, studies have investigated the pattern of information processing in patients compared to that normally observed in a healthy population in order to better understand the specific condition of the patients. On the other hand, pathological populations have been examined in order to understand self-consciousness in healthy functioning individuals. In this section we will briefly mention some pathologies including alterations of self-consciousness that have been the most usually studied with self-referential stimuli.

5.1. Self-processing and schizophrenia

Schizophrenia is probably among the most intriguing psychiatric disease. It has been suggested that some of its symptoms can be explained as disorders of different aspects of the self (Vogeley, 2003). Particularly, positive symptoms, hallucinations and delusions of control or of influence (i.e., consisting of experiencing actions, thoughts and feelings as control by a third part and in explaining these strange experiences in a delusional manner) seem due to deficits in self-monitoring (Jeannerod, 2003; Kircher & Leube, 2003; Lindner, Their, Kircher, Haarmeier, Leube, 2005; Vogeley, 2003). In other words, schizophrenic patients would have impaired abilities to recognize self- from other-generated actions or thoughts. This idea is supported by recent empirical evidence (Daprati et al., 1997; see Jeannerod et al., 2003 for a review). For instance, in a task involving recognition of one's own reproduced movements by a virtual hand, either identically or with some temporal or spatial deviations, performance of schizophrenic patients was impaired by comparison with performance of control subjects (Frank et al., 2001).

Other studies have investigated self-face recognition in schizophrenia with the similar idea that this ability is linked to self-consciousness and that self-consciousness is altered in this disorder (Irani et al., 2006; Kircher, Seiferth, Plewnia, Baar, & Schwabe, 2007; Lee, Kwon, Shin, Lee, & Park, 2007). However, these studies have led to far less consistent outcomes than studies about self-monitoring and self-agency. In a face identification task, schizophrenic patients were slower and less accurate to identify their own face than control subjects. This deficit was related to deficit in a theory of mind task (i.e., another component of self-consciousness and effective social coordination), supporting the idea that these two abilities are linked (Irani et al., 2006). In another set of three experiments involving self-face recognition in different conditions of presentation time, response hand, and location of presentation (Kircher et al., 2007), schizophrenic patients showed only few alterations of performance by comparison with control subjects. They made more errors when their own face was presented to their right hemifield (i.e., to their left cerebral hemisphere) compared to when other familiar or unfamiliar faces were presented and when compared to performance of control subjects. The authors nonetheless concluded to a specific alteration of self-face recognition in schizophrenia. Finally, in another study using a visual search task, self-face recognition was spared in schizophrenic patients. Indeed, although their reaction times were slower overall than those of control subjects when looking for objects, famous faces or self-face, they found their self-face faster than famous faces (Lee et al., 2007).

All these findings suggest that alteration of self-processing in schizophrenia is task-dependent (Lee et al., 2007). This is in line with Kircher and Leube (2003)'s conclusion that alterations of specific sub-systems (e.g., their function being for instance to represent the physical or mental outcomes of one's actions and thoughts) composing a more general self-system underlie the various symptoms found in schizophrenia, rather than a general disturbance of this self-system. The connections between these sub-systems would result in the experience of being a self in healthy subjects and these connections might be disrupted in schizophrenia.

This hypothesis is supported by neuroimaging studies showing that cerebral areas supposedly implied in self-consciousness show anomalous specificities in schizophrenic patients. This is the case of midline cortical regions showing abnormal pattern of activity (Harrison, Yücel, Pujol, & Pantelis, 2007) or of the prefrontal cortex presenting a smaller grey matter volume (Sapara et al., 2007) in schizophrenic patients by comparison with healthy subjects. Moreover, relations between the right dorsolateral prefrontal cortex and the medial frontal cortex, two regions playing important functional role in self-consciousness (see Northoff & Bermpohl, 2004), seem to be strongly lowered or even abolished in schizophrenic patients (Salgado-Pineda et al., 2007).

Self-referential stimuli and tasks can therefore be of crucial importance to understand this intriguing illness further. The examination of performance of patients in tasks implying self-processing seem a promising way to point out their specific difficulties ultimately allowing the establishment of targeted treatment strategies.

5.2. Self-processing and disorders of consciousness

After partially recovering from coma, some severely brain damaged patients are in a state characterized by wakefulness but without presenting any sign of explicit consciousness or self-consciousness. It is thus crucial from ethical and clinical points of view to find an efficient way to evaluate their state. Self-referential stimuli have sometimes been used to assess residual self-consciousness in these non-communicative patients. It seems that cerebral responses measured with electrophysiological and neuroimaging techniques during presentation of self-referential stimuli allow a more objective estimation of responsiveness in these patients than bedside observation (see Laureys, Perrin, & Brédart, 2007, for a review).

For thirty years, one’s own name has been shown to elicit differential brain response by comparison with other stimuli in healthy subjects, as measured by event-related potentials - ERPs (Fischler, Jin, Boaz, Perry, & Childers, 1987; see also Berlad & Pratt, 1995; Folmer & Yingling, 1997; Perrin et al., 2005). More recently, it has been shown that the patient’s own name is also more efficient than other non-self-referential stimuli to elicit neuronal and behavioural responses in non-communicative patients (see Laureys et al., 2007), and even more if it is spoken by a familiar voice (Holeckova, Fischer, Giard, Delpuech, & Morlet, 2006). In this context, the presentation of the own name is thus of particular interest to try to determine the seriousness of patient’s cerebral damage.

In a recent study (Perrin et al., 2006), ERPs recorded during self-name presentation showed that some (i.e., 3 out of 5) vegetative state patients (VS, i.e., awake but unaware of the environment or of the self) can present the typical P300 wave observed during cognitive processing of deviant stimuli in healthy subjects. This P300 was observed in all those in a minimally conscious state (MCS, i.e., awake and presenting only minimal signs of awareness of the environment and of the self). However, with the difference between MSC and VS patients being non-significant, the authors concluded that this ERP component is not usable to discriminate VS and MCS patients efficiently. Moreover, this partially preserved P300 response is not necessarily a sign of self-consciousness since it does not demonstrate that these patients explicitly recognize their own name. Indeed it might be that this response only reflects a conditioned orienting response (Laureys et al., 2007). Self-referential stimuli are thus useful stimuli to enhance chances of eliciting responsiveness in coma survivors but it is to date difficult to conclude about their efficiency to measure self-consciousness per se in these patients. Nevertheless, it has been suggested that responsiveness to these stimuli by VS patients could also have a prognostic value for their evolution to MSC (see Di et al., 2007).

5.3. Brain alterations and self-related misidentifications

Some neurological conditions[3] can generate specific disorders of the self (see Feinberg & Keenan, 2005 for a review). These conditions "alter the relationship between the individual and their body as seen directly or in a mirror, or their personal relationship to significant persons, places, or objects in their environment" (Feinberg & Keenan, 2005, p. 665) and have been labelled "delusional misidentification syndrome" (DMS). They would imply dissociation between recognition and identification processes (Ellis & Lewis, 2001; Papageorgiou, Lykouras, Ventouras, Uzunoglu, & Christodoulou, 2002).

In the Capgras syndrome, patients correctly identify a familiar face but have the delusional belief that the person is actually an impostor that has taken the place of the familiar person (hypoidentification, see Ellis & Lewis, 2001 for a review). This syndrome would result from a lack of appropriate emotional reactions to the familiar persons even though facial information is processed adequately (Young, Reid, Wright, & Hellawell, 1993). These delusional

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[3] Note that delusional misidentifications can actually have various origins ranging from psychiatric disorders to organic illnesses (e.g., Ellis & Lewis, 2001; Henriet, Haouzir, & Petit, 2008).

misidentifications can also concern objects, places or parts of one's own body - often the upper limb (Feinberg & Keenan, 2005; Paysant, Beis, Le Chapelain, & André, 2004). This last case has been labelled asomatognosia. Conversely, in the Frégoli syndrome, the patient believes that a familiar person is taking the appearance of another unfamiliar person (hyperidentification). This delusional misidentification can also concern the patient him or herself (Feinberg, Eaton, Roane, & Giacino, 1999). These DMS often follow alterations of the right hemisphere, particularly of the frontal and also parietal cortices, which might therefore play an important role in self-consciousness (Feinberg & Keenan, 2005; see also Miller et al., 2001 for a similar claim following the observation of changes in self in patients with frontotemporal dementia).

Difficulties with self-recognition can also be observed following neurodegenerative disease such as Alzheimer's dementia (AD), concurrently with the disappearance of explicit self-consciousness. Here the misidentification in the mirror rather results from a deficit in reasoning (Brédart & Young, 2004). Indeed, some patients lose the ability to recognize themselves in the mirror and identify their reflection as another person while they can still recognize other people (Bologna & Camp, 1997; Breen, Caine, & Coltheart, 2001). However, this "mirror sign" appears in a larger context of cognitive deterioration (and among other kinds of misidentification, see Nagaratnam, Irving, & Kalouche, 2003). It seems that this absence of self-recognition results from the fact that the patients become unable to understand the mirror spatial relations and unable to conceive that the mirror shows their own reflection (Breen et al., 2001; de Ajuriaguerra, Strejilevitch, & Tissot, 1963). They can interact with their reflection as if it was another person or show paranoid reactions. Some authors have even suggested that so-called "delusional misidentification syndroms" should not be considered as a syndrome but rather as a symptom (Nagaratnam et al., 2003), which seem quite obvious in Alzheimer's disease case. Some intervention can take place in order to help patients recover mirror self-recognition capacity but of course, due to the nature of the disease, its effect is temporary (Bologna & Camp, 1997). However, this last point maybe highlights the possibility of a residual self-consciousness in these patients in the absence of explicit spontaneous self-recognition and their responsiveness to self-referential stimuli might be assessed with electrophysiological measures (Folmer & Yingling, 1997).

By contrast with what has been shown with mirror self-recognition, it seems that patients with moderate to severe AD have less difficulties to identify pictures of their own face or their written own names than pictures or names of other people (i.e. their fellow residents). However, they had less difficulties with their printed own name than with pictures of their own face (the same was true with stimuli related to their fellow residents, Gross et al., 2004). The authors suggest that this might be because the own name is more stable across life than the own face. Accordingly, it has been shown recently that the deficit of self-recognition from pictures at a late-stage of AD is temporally graded. Indeed, a study conducted of a patient with late-stage AD have shown that she had a residual ability to recognise pictures taken in her twenties whereas she could not recognise pictures taken recently (Hehman, German, & Klein, 2005). Of course, self-recognition deficit is linked to the evolution of the disease and increases as the disease progresses. It rather occurs at later stages of the disease (Bologna & Camp, 1997; Breen et al., 2001; de Ajuriaguerra et al., 1963; Grewal, 1994; Molchan, Martinez, Lawlor, Grafman, & Sunderland, 1990).

By contrast with DMS, prosopagnosia is a specific facial recognition impairment. It is characterized by an inability to process facial information and to recognize familiar people. This inability extends to the patient’s own face (Brédart & Young, 2004). However, reasoning ability is intact and prosopagnosic patients remain able to identify familiar persons on basis of other clues such as gait, voice, or clothes. Similarly, when facing a mirror they understand without difficulty that they are the source of the mirror reflection (de Ajuriaguerra et al., 1963). Even though self-face processing is altered in this condition, it is not a specific alteration of the self since it generalizes to all familiar faces.

It is interesting to note here that these difficulties with face identification or recognition can sometimes exist in healthy subjects. Brédart and Young (2004) asked students to report cases in which they experienced transient difficulties to recognize themselves or felt a strange impression when seeing their own face. They found that these experiences could be related to some disorders described above. For instance, some participants reported that they did not recognize their own face on pictures or on videos but inferred that it was themselves because of the context or their memory of the event depicted. This recognition failure can be related to that experienced by prosopagnosic patients. Other participants reported having experienced a transitory mirror-sign in the sense that they misidentified their mirror reflection as another person. However, such experiences generally occurred when they did not notice the presence of a mirror. Finally some participants reported recognizing their own face but with a feeling of strangeness (i.e., because the image they were seeing did not match their representation of themselves, see also Section 2.1. of Chapter 2) as can be experienced by Capgras patients. None of those participants reported reality monitoring difficulties as can be found in patients with dementia or in some DMS. This study thus highlights the importance of decisional processes in conditions entailing impairments of face recognition and identification.

Some authors claim that the examination of the neurobiology underlying all these conditions might represent ways to understand further the neurobiology of the self and self-consciousness (Feinberg & Keenan, 2005). However, as we have seen in this section, self-related deficits associated with these various neurological conditions are actually often parts of larger cognitive and/or emotional impairment. Moreover, “disruption to any given area is rarely an isolated event” (Feinberg & Keenan, 2005, p. 673). In most cases, it might therefore be difficult to strictly link self alterations with specific brain lesions.

5.4. Conclusion

Through this section one has probably noted that disrupted processing of self-referential stimuli is often linked to disrupted self-consciousness or to an altered sense of self. These alterations of self-processing often found their origin in functional (e.g., in schizophrenia) and/or anatomical troubles of brain organization and architecture (e.g., in acute brain lesion or schizophrenia). This probably illustrates, as previous sections did, that self-consciousness and its various levels of manifestations are related to the nature and level of encephalization of the human brain. However, each of the condition reviewed above has its own specificities. As a consequence, all self-referential stimuli are not as appropriate as each other to study impairment of self-processing in all these cases (for instance visual self-recognition is certainly not the most impaired feature of self-consciousness and self-processing alterations are often quite extended in the cases mentioned here) and they can be used with different purposes.

Indeed, among all these conditions some only imply alterations of some aspects of self-consciousness while other are intact (for instance visual self-face recognition can be relatively preserved while self-monitoring is more impaired in schizophrenia). Patient's reactions (behavioural or neurophysiological response) to self-referential stimuli are then examined either to understand their condition and ultimately help them to cope with it, or to get new insights about the functions of self-consciousness and how it emerges in the brain. Conversely other conditions imply alterations of more if not all aspects of self-consciousness (such as in vegetative state or dementia) but in a context of general cognitive impairment. In such cases of non-communicative patients, researchers take advantage of the salience of self-referential stimuli to try to find signs of self-consciousness (or at least of responsiveness) otherwise difficult to detect.

6. Conclusion

We have started this chapter by trying to define self-consciousness. We have seen that self-consciousness is a multi-faceted concept covering the simplest forms of self-world differentiation to the most elaborate forms of knowledge about oneself as a part of a broader social environment. The lesson one should probably have learnt throughout this chapter is that having a clear definition of self-consciousness before starting to investigate it is crucial. Indeed a lack of precise definition and of positioning about the specific level of self-consciousness one is examining has probably been a main source of recurring debates in the literature. Self-consciousness encompasses so many aspects that it is difficult to study it in its entirety.

In this chapter we asked whether self-referential stimuli could constitute an efficient way to study self-consciousness. An overall answer might be “yes, sometimes, but on the condition one knows exactly what one is studying”. Indeed, a result of the multiplicity of the concept of self-consciousness is that specific self-referential stimuli or self-referential processing can probably not allow studying it in its entirety. Depending on the type of stimulus and of the task at play, different aspects of self-consciousness will be examined. For instance, a self-face recognition task is of little use to understand how people define their own goals or values throughout their lives (Morin, 2002, 2007).

In this thesis, we are mainly interested in visual presentation of self-referential stimuli (i.e., the own face or body). We have seen in the present chapter that these stimuli can be used to study some aspects of self-consciousness but certainly not the more elaborated and abstract ones as they mostly refer to one's own physical appearance. Even if the physical appearance provides fundamental information about one's own identity and may be crucial to build a united representation about oneself, only a kinaesthetic representation of one's own body is necessary and sufficient for its self-conscious processing.

Still we have seen throughout this chapter, that the use of visual self-referential stimuli is useful to test nonverbal or preverbal organisms (Bard et al., 2006). The fields of studies reviewed above have shown that the processing of self-referential stimuli can be used (more or less successfully) to detect self-consciousness in those cases in which the organism is not able to communicate explicitly about its own self-consciousness (animals and infants). By doing so, comparative studies have found that self-recognition (and therefore possibly an elaborated form of self-consciousness) is limited to animals with sufficient levels of encephalization and corollary of cognitive abilities. Developmental studies have also abundantly used visual presentation of self-referential stimuli and have elaborated thoughtful theories of self-consciousness from children's reactions to these stimuli. Salience of self-referential stimuli is also useful to assess severely brain damaged patients (Laureys et al., 2007) or patients with neurodegenerative diseases. However, in the context of general cognitive impairment, little can be inferred about self-consciousness.

Finally, we have seen that presentation of self-related stimuli is a (the unique?) way to elicit self-related response in the brain. Researchers have investigated which regions of the brain are particularly involved during self-processing in healthy subjects or which regions are impaired in patients with a disorder implying some disruption of self-processing to infer the neural correlates of self-consciousness.

Cautious researchers might therefore keep in mind the exact definition of what they are studying and avoid drawing over ambitious conclusions from their specific findings. Only after this step is achieved can an integrated work be possible. Neuroscientists have already embarked on this, specifically trying to extract common neural signatures of self-consciousness from existing studies. But will this approach be successful, to date very little is known about functions of self-consciousness and how this subjective feeling can emerge from time to time in a more or less complex form from the organic matter of the brain.

Now, after questioning the possibility of studying self-consciousness with self-referential stimuli, another legitimate question arises. This question concerns the specificity of these stimuli. Are they really special and different from other stimuli? This is an important question because if it is not the case, this would in turn question their use for a proper evaluation of self-consciousness.

Chapter 2

DO SELF-REFERENTIAL STIMULI POSSESS SPECIFIC PROPERTIES?

1. Origin of the question

Another wave of research has studied self-referential stimuli, with the assumption that they constitute a special class of stimuli. Similar hypotheses have been formulated regarding other classes of stimuli such as faces (Bruce & Young, 1998; Kanwisher, McDermott, & Chun, 1997; Puce, Allison, Asgari, Gore, & McCarthy, 1996; Yovel & Kanwisher, 2004; but see Farah, Wilson, Drain, & Tanaka, 1998). In the case of self-referential stimuli, this claim probably results from the hypothesis that information pertaining to ourselves, with the privateness and subjectiveness that it implies (see previous chapter), is different and has unique properties in comparison with other kinds of information. However, it has been shown recently that evidence is to date insufficient to support such a claim (for a review, see Gillihan & Farah, 2005). In the present chapter, we will therefore examine whether self-referential stimuli possess specific properties by comparison with non-self-referential stimuli and if they really are processed differently. We will approach this question with regard to three main topics. The first one will concern the memory domain and the way self-referential stimuli are represented. The second point will address the question of neural correlates subtending processing and representation of self-referential stimuli. Finally, in a last point, the attentional properties of self-referential stimuli will be examined. Throughout this chapter, our interest will mainly reside with the self-face but other kinds of self-referential stimuli will also be briefly discussed when appropriate.

2. Representations of self-referential stimuli in memory

In their review examining whether the self is special, Gillihan and Farah (2005) distinguish physical and psychological aspects of self and self-related stimuli. As already mentioned in the previous chapter, the self-face and the physical appearance in general pertain to physical aspects of oneself. Other characteristics such as knowledge about oneself or autobiographical memory rather refer to psychological aspects. Contrary to Gillihan and Farah that mainly reported data relative to the psychological self, here we will particularly look at data relative to one's physical aspects and how they are represented.

2.1. Special representation of one's own physical appearance?

Representation of the self-face

Even though our own face is a face just like any other to other people's eyes, this is not the case from our own perspective. Indeed, unlike other faces, we cannot see our own face directly. Because our eyes are part of our face, we need a reflecting surface to see it (Gregory, 2001). Therefore, we mainly see ourselves through mirrors and also occasionally on pictures or on videos. This physical constraint implies that we do not access the same variety of viewpoints, luminosity conditions, facial configuration changes, emotional expressions and so on as for other faces. In other words, the experience we have of our own face is different from that we have of other faces. Several studies reviewed below have tried to investigate whether these unique physical constraints affect the way our own face is represented in memory and as a consequence the way it is recognized (in order to be able to recognize an object from memory, a mental representation of this object must first be constructed).

Thirty years ago, Mita, Dermer, and Knight (1977) offered some of the first experimental evidence of the consequence of the perceptual constraints concerning our own face. They were interested in the generality of mere-exposure effects consisting in increasing one's evaluation of a stimulus after having been repeatedly exposed to this stimulus. They presented their participants with pictures depicting their own face either in a normal or in a mirror orientation. Participants were asked to judge which image they *preferred*. The same judgment has to be made by participants' lover or friend. It appeared, in line with mere-exposure hypothesis, that participants preferred the mirror image version of their own face while their friend and lover preferred the normal version. In another study (Rhodes, 1986) using a similar procedure and where participants had to indicate which picture (normal or mirror-reversed) was *most representative* of themselves, participants also chose the mirror-oriented version more often than the normal picture. In a second experiment, participants had to make the same judgment between two face composites (one made up of the left half of the face, and another one made up of the right half of the face). This time, no difference was found between the two conditions.

More recently however, a similar setting also including face composites showed that participants tended to choose a composite face made up of the right hemi-face as most representative of themselves but also of their friend (Brady, Campbell, & Flaherty, 2004). However, the difference between both cases resides in the fact that in the first case (one's own face) the right hemi-face lays in one's right hemifield when looking in the mirror while the reverse is true for the latter case (i.e., the right hemi-face of someone else lays in one's left hemifield when looking at him or her). This suggests the existence of a differential hemispheric bias for both types of faces (see Section 3 of the present chapter). Moreover, when asked to choose between a normal or a mirror-reversed picture the one that fit more with their representation of themselves, participants chose their own face as a mirrored-image.

This team conducted another study using a similar procedure including composite faces but replaced the judgment from memory by a matching task (Brady, Campbell, & Flaherty, 2005). Participants had to judge which composite looked more like an original picture presented simultaneously either in normal or mirror-reversed orientation. Choices for the self-face was at random level in both cases maybe reflecting the fact that we see our own face in the mirror but also on pictures. In agreement with their previous study, when the friend's face was concerned and presented in its usual normal orientation, 80% of participants chose the composite made up of the right hemi-face (lying in the observer's left hemifield). However, when the original face was presented in a mirror-reversed orientation, this bias towards the hemi-face lying in the left hemifield was reduced to 62%, which indicates a competition occurring between the perceptual process and the memory representation. These findings suggest that information about configuration and global orientation of familiar faces is represented in memory.

Taken together, most of these results indicate that the way we mainly see our own face directly influences the way it is represented in memory, i.e. with a mirror-reversed orientation. However, the same is true about other personally familiar faces that are also represented the way we see them when facing them. As such, it would appear premature to claim that the representation of the self-face in memory is special. We can imagine that similar physical constraints applied to other objects have comparable consequences. For instance, we can reasonably assume that Continental Europeans and Americans have a representation of dashboards with the steering wheel located on the left and the glove compartment on the right. By contrast, British people or Australians must have a reversed representation with the steering wheel on the right. Unfortunately, we have not found studies that have investigated this topic in the literature.

In another study investigating more precisely the type of information used to judge the most usually encountered view of the self-face (i.e., mirror view) and of a friend's face (i.e., normal view), it has been shown that this information is not the same in both cases (Brédart, 2003). Indeed, even though judgment accuracy was similar for both faces, participants tended to use asymmetrically located cues such as scars or moles for their own face. By contrast, they rather used the global configural information for the other familiar face. Other perceptual consequences of our main exposition to frontal view of our own face through mirrors have been reported. For instance, a study has shown that we tend to underestimate our own nose's size (Thompson, 2002). Indeed, when asked to represent their nose length on a vertical line, participants drew it about 12% shorter than the actual size. Thompson explains this finding by the observation that the edge of noses forms a certain angle from the vertical but that noses are perceived as a vertical line when faces are viewed from a frontal viewpoint. This results in a perceived shortened size by comparison with the actual size. Participants also tended to overestimate the distance separating their two pupils by 32%. However, this finding could not be explained by the same account and the reason for it is still unknown. Unfortunately, this experiment did not include other faces and these effects might apply to other faces as well.

All the studies reported so far investigated representation of familiar faces as seen from a frontal viewpoint. However, as we already mentioned, the physical constraints pertaining to our own face result in a more restricted range of viewpoints (i.e. near-frontal view in most cases) by comparison with other faces that we can see all the way around. This also directly affects the canonical view (i.e., the position in which an object is the most easily identifiable) of our own face (Laeng & Rouw, 2001; Troje & Kersten, 1999). One study examined the time necessary to name one's own face and colleagues' faces presented in frontal and in profile views (Troje & Kersten, 1999). Results showed that participants were faster to name their own face than the other faces, presumably because of their own name was more familiar than the other names. In addition, they were faster to name their face in the frontal view than in the profile view whereas this view effect was non-significant for the other familiar faces (even if the same trend than for the self-face was observed). According to the authors, this suggests that familiar faces and more generally familiar objects are represented in a viewer-centred way rather than in a viewpoint-independent or object-centred way.

In another study, the canonical view of familiar faces was investigated more precisely by including intermediate viewpoints (i.e., 22.5° and 45° deviations on a vertical axis from the frontal view) between frontal and profile views (Laeng & Rouw, 2001). Participants performed a face-name matching task on faces varying in their degree of familiarity (i.e. recently learned face, moderately familiar face, highly familiar face and self-face). Results showed that participants were the fastest with their own face presented frontally by comparisons with other orientations whereas they responded globally faster with the other familiar faces for views deviated by 22.5°. However, for highly familiar faces (i.e. a friend's face) frontal and 22.5° views elicited similar performance. Consistently with Troje and Kersten (1999)'s conclusion, these results suggest that representation of faces is viewer-centred (see also Ewbank, Smith, Hancock, & Andrews, 2008; but see Eger, Schweinberger, Dolan, & Henson, 2005; Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2005 that showed that this effect is modulated by familiarity) and that the differences observed between the self-face and other faces reflect differential visual experience between those faces (here again we can imagine that people tend to represent dashboards rather from a frontal viewpoint just as the self-face).

Another consequence of our eyes being part of our own face is that we do not access the same range of facial configurations resulting from various facial (emotional) expressions. This might also influence the representation we have of our own emotional facial expressions. Studies interested in familiar face processing have shown that facial expressions influence the recognition of familiar faces (Endo, Endo, Kirita, & Kinya, 1992; Gallegos & Tranel, 2005; Ganel & Goshen-Gottstein, 2004; Kaufmann & Schweinberger, 2004; Kirita & Endo, 2001). However, there are only a few studies regarding the self-face. Brédart and Young (2004) have examined the everyday difficulties people can experience with self-face recognition. They have reported that people sometimes recognized themselves but perceived some unusual aspects (e.g. when a picture of their own face did not correspond to the image they have of it). In most cases, this unusual aspect was due to the facial expression of the self-face and to the fact that people did not know that their face looked this way when showing a particular expression.

In 1979, Yarmey conducted a study on self-recognition of facial poses. He assessed whether people are able to recognize certain facial configurations that they project to give a certain image of themselves to others as a function of the social situation (i.e., sociable, intelligent and trustworthy poses). He also hypothesized that by contrast to these changing representations we might have a representation of our "real self", i.e. a prototypical representation of ourselves. He examined which facial pose better approximated the participants' "real self" by asking them to pick up the best picture of their "real self" among the various self-pictures. Women mostly chose pictures where they projected a sociable self while men chose the sociable as well as the trustworthy poses. In a subsequent memory test, he found that people better recognized sociable poses (65% accuracy), then trustworthy poses (45%), and finally intelligent poses (42.5%). Moreover, women were better than men at recognizing their real self and their most sociable poses. These two studies furnish interesting insight about our knowledge of the way we look like when expressing specific facial poses or emotional expressions. They indicate that this knowledge is not perfect. However, they do not give direct comparison about our capacity to accurately deal with other familiar people's facial expressions and poses.

In her study involving facial composites described above, Rhodes (1986) found that the participants' preferential choice towards the mirror-reversed version of their own picture was no longer present for smiling faces. With regard to smiling pictures of other highly familiar persons, participants rather chose the normal-oriented pictures. This might also result from the specific experience related to one's own face. On the one hand, we usually have a neutral expression in front of the mirror and we rarely see ourselves showing emotional facial expression but on the second hand, we usually smile on pictures. The two types of experience might thus compete when participants have to judge smiling pictures (Rhodes, 1986).

All the studies reviewed above thus indicate that the particular experience we have with our own face seems to affect the way it is represented in memory. Apparently, we just represent it the same way we usually perceive it. However, these studies do not really lead to the conclusion that the self-face is special and processed in a qualitatively different way from other faces. In addition, it is well documented in the literature that familiar faces elicit different patterns of performance by comparison with unfamiliar faces, at least on specific tasks (Ellis, Sheperd, & Davies, 1979; Megreya & Burton, 2006; Young, Hay, McWeeny, Flude, & Ellis, 1985), and that unfamiliar faces that become familiar will undergo changes in the way they are processed (Bonner, Burton, & Bruce, 2003). The self-face might just be a hyper-familiar face (e.g., just like our mother or partner's faces) that we access in a particular way. Research on object perception has also brought some data in favour of viewer-centred representation of objects other than faces (Tarr & Pinker, 1990; Wilson & Farah, 2003) or scenes (Garsoffky, Schwan, & Hesse, 2002) in some situations. Therefore, at this point, we cannot conclude about the specificity of the self-face. Moreover, we have still only sparse information about the robustness and efficacy of the representation of our own face.

That is what Tong and Nakayama (1999) investigated using visual search tasks. They introduced the concept of "robust representation" to define the representations characterising highly familiar faces. They characterise robust representations according to five properties (p.1017): They "(1) mediate rapid asymptotic visual processing; (2) require extensive visual experience to develop; (3) contain some abstract or view-invariant information; (4) facilitate a variety of visual and decisional processes across tasks and contexts; and (5) demand less attentional resources". Tong and Nakayama confirmed their view that the self-face benefits from a robust representation by showing that the self-face was found as target or rejected as distractor in a faces-array more quickly than stranger's faces. This was true even after hundreds of trials (allowing the stranger's face to get more and more familiar during the time course of the experiment) and when faces were presented in atypical orientations (i.e., three-quarter and profile views, or upside-down orientation). This study therefore shows that the physical constraints relative to our own face do not prevent it from benefiting of an efficient representation. However, as no other highly familiar faces were included as control in this study, it does not inform us whether this robust representation being specific to the self-face or not.

Advantages in terms of reaction times for the self-face relative to other familiar faces have nonetheless been reported elsewhere in various situations (Keenan et al., 1999; Sui, Zhu, & Han, 2006; Troje & Kersten, 1999; but see Kircher et al., 2000, 2001; Platek et al., 2006). However, previous researchers did not document the accuracy or the preciseness of the representation of the self-face that could be different from that of another familiar face (maybe Thompson, 2001's study constitutes an exception to that point but it did not include other familiar faces). Determining accuracy of the representation of our own face will be one of the practical aims of this work (See Chapter 4).

Studies presented above focused on visual recognition of one's own face. Some researches have been conducted to examine the relationship between visual self-face recognition and other sensorial modalities. In a recent study, Casey and Newell (2005) have investigated whether robust visual representation and long-term familiarity characterising one's own face can be shared across different sensorial modalities. They built plaster models of their participants' faces and asked them to recognize their own face model from touch among seven other distractor model faces in a line-up procedure. Participants performed at chance and were unable to recognize their own face only tactically. However, performance increased when they were allowed to touch their own face beforehand. The best performance however was found when participants had to visually recognise the model made up from their own face. In a second experiment, they used a different visual-tactile matching procedure employing recently learned and novel faces. They found better cross-modal matching performance for familiar faces by comparison with unfamiliar faces. Authors conclude that the shape of one's own face is not represented in memory and that high familiarity of one's own face does not elicit multi-sensory recognition. They also posit that the representation of one's own face might be qualitatively different from representation of other faces. However, their study does not allow such a conclusion since no direct comparison between participants' ability to tactically recognise their own face and another familiar face was allowed by their design. Moreover, recognising one's own face in such conditions is totally different from encoding conditions that can be found during a real-life tactile exploration of one's own face since touching our own face is characterised by this unique double-touch condition (Rochat, 2003).

Platek, Thomson, and Gallup (2004) adopted what could be qualified as a converse approach and examined whether the recognition of the self-face can be affected by other self-related information from other sensorial modalities. To do so, they exposed their participants with their own odour (versus another odour) and with their own name (versus other names; a familiar and an unfamiliar name) presented visually or aurally while they were performing a face identification task. They found that all three self-related kinds of information facilitated self-face recognition in terms of reaction times by comparison with a control situation with no prime. They did not find the same facilitation effect for either familiar or unfamiliar faces. They concluded that this particular cross-modal facilitation for the self-face argues in favour of a highly integrated cerebral network dedicated to the self. However, as Brédart (2004) has noted, this cross-modal facilitation is not specific to the self-face and has been demonstrated with other faces (see for instance Ellis, Jones, & Mosdell, 1997). Platek, Thomson, et al. (2004)'s results can therefore not advocate for a qualitative difference between the processing of one's own face and the processing of other faces. Brédart (2004) posits that these results rather reflect a quantitative difference in the sense that this cross-modal facilitation could just be higher for self-face recognition than for other face recognition. More precisely, the integration process might be more complete for ourselves than for other people due to our expertise on ourselves.

Representation of the self-body

Just as it is the case with our own face, we have a particular experience of our own body, but not in the same sense. Contrary to our own face, we can see our own body directly (at least most of its parts). Unlike other bodies however, we see it from above, in a kind of upside-down way (Gregory, 2001). On some occasion, we can see it from head to toe in mirrors or on photographs but probably less frequently than our own face. Only few studies have examined how our own body-shape or body parts other than the self-face are represented in memory (see Gillihan & Farah, 2005).

One early study investigated the stability and accuracy of the body-image by means of a mechanically distortable mirror (Traub & Orbach, 1964). The authors noted that even if from a physical point of view our body is relatively stable during adulthood its representation might be quite plastic since body-perception changes can occur in various situations in healthy subjects (e.g., under influence of hallucinogenic drugs, in situations of sensory deprivation, fatigue, stress, and so on) or in pathological populations. They used a mirror deformable on the vertical and horizontal axis that participants had to adjust by means of four three-position switches until they obtain their undistorted reflection. They compared performance of healthy subjects and psychiatric inpatients and found that most of them were able to correctly adjust their reflection. Three psychiatric patients out of ten adjusted the mirror in a way their image was distorted and one left the room when he saw his distorted image. It appeared that participants who could not adjust the reflection accurately also had difficulties with other psychophysical tasks involving their body or other objects. The authors thus pertinently conclude that such cases do not constitute specific alteration of the body-image. Moreover, as no control task with other persons was included, it is difficult to conclude about the specificity of the representation of the self-body.

Later, Collins (1981) tested the extent to which adolescents were able to identify their body accurately and which parts they judged important to identify themselves. He photographed his participants in three different positions, i.e., frontal, profile and rear orientations. One month later he asked them to pick out their own full body (the head being occluded) or various body parts within arrays composed of several pictures. Results showed that females better recognized their full body than males, in all three orientations. Apart from the head that was the best recognized body part (100% accuracy except in the rear orientation), females made the most accurate judgments with their breasts and males with their genitals. The lower limbs were not important cues for identification. Moreover, males made their judgments quicker than females. Although interesting, this study did not include a familiarity control. Moreover, it did not report systematic analyses of the effect of the viewpoint.

In a recent study Jokisch, Daum, and Troje (2006) addressed this question with dynamic stimuli. They were interested in the effect of the viewpoint on the recognition of one's own body motions. They presented their participants with walking patterns represented as point-light displays that had been acquired from a frontal, a half profile or a profile viewpoint. These walking patterns were their own or those of 11 other familiar persons (friends or colleagues) and participants were to identify and name the walker. First, it seems that the task was quite difficult since correct identification rates were around 25% but still above chance level. Nonetheless, it appeared that participants could identify themselves independently of the viewpoint while they better recognised other people from frontal and half profile views by comparison with the profile view. The authors suggest that these results may be due to our specific experience with our own movements and with others' movements. Indeed, while we usually attend to others approaching us, increasing the exposure to frontal and half profile views, we might in our own case transfer our motor perceptions to visual representations. In other words, as in the case of the self-face, these differences of performance might just reflect a differential experience.

In order to test whether the representation of one's own body shape is reliable, Daury, Brooks, & Brédart (submitted) have used a psychophysical method involving pictures of the participants and their friends. In some pictures, the waist-to-hip ratio was modified by gradual steps of 2% up to 10%. Participants had to judge from memory whether the images were intact or altered. Results showed that the representation of one's own body-shape is accurate but not very precise. Indeed, participants' judgments on intact pictures were similar in the recognition memory task and in a control perceptual discrimination task. However, they accepted as intact bodies that had been altered to larger amplitude than participants from the perceptual discrimination task. Moreover, performance was similar for the own body shape and for the friend's body shape. This study thus suggests that we represent our own body similarly to bodies of other familiar persons.

In sum, to date the few existing studies do not allow a firm conclusion that the representation of one's own body-shape is special by comparison with others. Also, unsurprisingly these data indicate that the identification from body-shapes and the memory representation of bodies is less reliable than the memory for faces.

2.2. A word about other self-referential stimuli

Contrary to the physical constraints touching our own face, we have a privileged access to psychological information about ourselves (e.g., our autobiographical memories, our personality traits, and so on). This can lead to increases of performance in tasks comparing self-referential information to non-self-referential information. The well known self-reference effect (SRE) illustrates this point. It consists in better memorising traits or other kinds of material when they have been encoded with reference to oneself than with other kinds of encoding (e.g., semantic encoding, for a review see Symons & Johnson, 1997). However, it has been shown that SRE is dramatically reduced or even eliminated when the self-reference is compared to a reference to another familiar person (Kuiper & Rogers, 1979; Kuiper, 1982). It seems that crucial factors for the emergence of SRE might be the elaboration and organization of the encoded information (Symons & Johnson, 1997) and these properties might not be specific to the self-reference (Gillihan & Farah, 2005).

2.3. Conclusion

We have seen throughout this chapter that we have special experience with self-related information. On the one hand, we clearly access our physical appearance in a different way than other people's appearance (i.e., indirectly and mainly via mirrors for our own face, and directly but from above or via mirrors for our own body). However, this does not seem to affect much the way we represent it in memory. When controls of familiarity are included (which is far from being systematically the case) allowing an accurate evaluation of the specificity of the self-face representation, the differences that are found between the self-face and other faces clearly reflect the differential experience during encoding and construction of the representation. No data to date can really attest that these differences could not exist in other cases (as with the dashboards example).

Moreover, we have seen that despite the particular way we access our own face its representation seems to be robust, at least in term of processing speed (Tong & Nakayama, 1999). Here again however, studies do not always allow us to disentangle simple familiarity effects from self-effects. In addition, existing data have not yet really tested the accuracy of the representation of one's own face. In sum, we could say that particularities entailed by physical constraints related to our own physical appearance can have some consequences on the way it is represented. However, these consequences seem in line with more general characteristics of our visual system and could apply to other faces or objects.

On the other hand, we have a privileged access to our own psychological aspects. This leads to good performance with self-related stimuli. However, the specificity of self-related stimuli is also questioned when adequate controls of familiarity effects are included (see Gillihan & Farah, 2005 for a review).

Instead of examining the specificity of self-related representations, another way to address the question of the specificity of self-related information is to examine whether they involve specific brain areas by comparison with non-self-related information.

3. Self-referential stimuli and the brain

Now that we have examined the specificity of self-related information in the way they are represented, we will examine the neural correlates underlying the processing of these information and their representations. Indeed, even though we have seen that representations of self-referential stimuli do not seem qualitatively different from representations of non-self-referential stimuli, it is still possible that both kinds of representations are subtended by different brain regions. Neural correlates of self-related processing have been examined in various ways such as behavioural experiments, event-related brain potentials, PET scan, functional magnetic resonance imaging or examination of split-brain patients. This topic has recently benefited from a growing interest among the neuroscientific community. If one considers all the aspects and all kinds of information pertaining to the self, the increasing number of existing studies results in a huge literature. Therefore, we will not seek for exhaustiveness here and we will mainly remain focused on studies examining visual self-recognition.

3.1. Neural correlates of visual self-recognition

In recent years, brain regions involved in self-face recognition have been extensively studied. Controversies as to the hemispheric dominance of self-face recognition have emerged and a consensus about the precise anatomical locations implying this function has still to be found. A few studies interested in neural correlates of body-shape recognition have also been conducted. These studies are reviewed below.

Behavioural data

A first range of studies interested in the hemispheric dominance of self-face recognition have compared the performance of healthy participants with their right versus their left hand when responding to tasks implying the self-face. In a first study involving identification of three different faces (i.e., the self-face, another familiar face and a stranger's face) presented upright or inverted, Keenan and colleagues (1999) found that participants responded faster to their own face with their left hand than in all other conditions that did not differ between each other (see also Keenan, Ganis, Freund, & Pascual-Leone, 2000). They concluded that self-referential stimuli could be processed differently in both hemispheres, preferentially in the right hemisphere. Indeed, because of a contralateral motor control, a better performance with one hand suggests the dominance of the opposite cerebral hemisphere in the task at hand (for a review see Brown & Marsden, 2001). According to Keenan et al., this effect could extend to other self-referential stimuli and reflect a "self-effect" rather than just a "self-face effect" (for reviews see also Keenan, Gallup, & Falk, 2003; Keenan, Wheeler, Gallup, & Pascual-Leone, 2000). The same right hemispheric bias was found by the same team in another study with another task involving categorisational judgments instead of reaction times (Keenan, Freund, Hamilton, Ganis, & Pascual-Leone, 2000). In this study, participants were presented with movies showing two faces morphed together and gradually changing from the first face to the second face. Participants saw their own face or a co-worker's face morphed with a famous face and had to push a button with their right or their left hand when they judged that the face became more famous than personally familiar (or the other way round when the movie started by a famous face). When participants responded with their left hand, they saw their own face earlier in the sequence when the movies began by a famous face and saw it longer when the movies began by their own face (and changed into a famous face) by comparison with other conditions involving their right hand or the co-worker's face. In another study using a similar procedure with Chinese students (Ying, Jianli, & Jian, 2004) the same right hemispheric bias (or left-hand advantage) was found for the self-face but also for a friend's face in some conditions (i.e., when the face changed from friend's face to famous face but not in the reverse situation). This questions the specificity of this right hemispheric bias for the self-face.

This left-hand advantage for the self-face has nonetheless been replicated by others researchers from Keenan's group (Platek & Gallup, 2002). They related the reaction times to a face identification task with scores on a questionnaire assessing schizotypal personality traits (i.e., the Schizotypal Personality Questionnaire - SPQ) in a non-clinical population. The left-hand advantage for the self-face was found in individuals with a low score on the SPQ whereas a reversed right-hand advantage was found among individuals with a high score on the SPQ (i.e., individuals presenting schizotypal traits). According to Platek and Gallup, since the processing of self-related information presumably subtended by the right hemisphere is altered in schizophrenic patients, their study is an evidence of the relationship between self-face recognition, self-consciousness and the right hemisphere. Finally, in a study mentioned above (Platek, Thomson, et al., 2004, see Section 2.1. of this chapter), a left-hand advantage was found for the self-face during an identification task but no hand effect was found for other familiar or unfamiliar faces. However, this effect was only observed in the control condition where no visual, auditory or olfactory primes were involved.

This right hemispheric bias for the self-face has been questioned by other studies that have found the opposite bias or no hemispheric bias during self-face processing. In the study involving facial composites that we have already described above (see Section 2.1. of the present chapter), Brady and colleagues (2004) found that the self-face seems to be preferentially represented in the left hemisphere (the self-face's most representative composite being made up of the hemi-face that lies in one's right hemifield when looking in the mirror), while familiar faces would be represented in the right hemisphere (the friend's face most representative composite being made up of the hemi-face that lies in observer's left hemifield when facing the person).

In their study examining canonical views of familiar faces, Laeng and Rouw (2001, see Section 2.1.) were also interested in hemispheric dominances and presented the faces from each condition either in the observers' right or left visual hemifield. They found that the left hemisphere processed canonical views of familiar faces (i.e., deviation of 22.5° from a frontal viewpoint) more efficiently than the right hemisphere whereas the right hemisphere was more efficient with non-canonical views. Conversely, no effect of visual field was found for the self-face (presented in canonical or non-canonical views) suggesting that it is processed similarly by both hemispheres. The Laeng and Rouw (2001)'s finding illustrates how variables such as degree of familiarity or orientation of the faces can dramatically affect results in terms of hemispheric dominance. Note that the studies showing hemispheric dominance during processing of familiar faces contrast with other studies that did not find such lateralisation (see for instance Kampf, Nachson, & Babkoff, 2002).

Recently, using an adaptation paradigm, Rooney, Brady, and Benson (2007) found that viewing a highly distorted (i.e., compressed or expanded) stranger's face for five minutes similarly impacted attractiveness ratings of the self-face and a friend's face. Indeed, judgments of attractiveness on both altered familiar faces shifted in the direction of the adapting face. This indicates that the representation of the self-face and of other familiar faces is rapidly updated by visual experience. Even though this study does not give information about hemispheric lateralisation, it nonetheless suggests that representations of the self-face and familiar faces are subtended by shared mechanisms and neural populations.

Divided brain data

Lateralisation of self-face processing have also been studied with other methods including examination of split-brain patients (Keenan, Wheeler, Platek, Lardi, & Lassonde, 2003; Sperry, Zaidel, & Zaidel, 1979; Turk et al., 2002; Uddin, Rayman, & Zaidel, 2005), Wada test (Keenan, Nelson, O'Connor, & Pascual-Leone, 2001) or repetitive transcranial magnetic stimulation – rTMS (Théoret et al., 2004; Uddin, Molnar-Szakacs, Zaidel, & Iacoboni, 2006). The two first methods have in common the possibility to present the self-face to one active cerebral hemisphere at a time and to examine its capacity to process the self-face efficiently. The third method offers the possibility to disable or on the contrary to stimulate a particular brain region and to examine the effect of this manipulation on the realisation of a task. Unfortunately, studies using these various techniques have also yielded contradictory results.

Sperry and colleagues (1979) pioneered the area of hemispheric dominance with regard to self-information processing using split-brain patients. They have examined two of these patients and have shown that both hemispheres are capable of self-recognition when the self-face is presented unexpectedly. Moreover, they also found that both hemispheres could give similar responses to questions about preferences and knowledge concerning personal items, historical or political topics. More recently, Uddin, Rayman et al. (2005) also found that both hemispheres were capable of self-recognition. They presented a split-brain patient, NG, with morphed pictures. These morphs were either made up of NG's face and an unfamiliar face or from another highly familiar face and an unfamiliar face. Twenty-one pictures were created for each pair of faces (i.e., 2 originals plus 19 intermediates). In a first condition, NG was asked to push a button if the picture looked more like herself and another if the picture looked more like an unknown face. In a second condition, she received similar instructions but with the other familiar face. Analysed data included sessions in which pictures were presented either on her right or on her left visual field and where NG had to respond with the hand on the same side as that of the picture. Results showed no indication of a hemispheric specialisation for self-face recognition. By contrast, NG's left hemisphere was unable to recognise the other familiar face and this face could only be recognised by the right hemisphere.

In another study, Keenan, Wheeler, Platek, et al. (2003) have found a right hemisphere advantage for the self-face. They presented one patient, ML, with pictures depicting morphs of his own face with Bill Clinton's face (11 gradations from 0 to 100%) or of another familiar face (i.e. a lab assistant) morphed with the same famous face (11 gradations). All 22 pictures were presented in a random order at the centre of a monitor and ML had to look for his own face or for the other familiar face and to give his response either with his left or right hand. When he was instructed to judge whether parts of his own face were present in the morph, he recognised more pictures with his left hand than with his right hand and made more mistakes (i.e., chose a morph made up of the other familiar face) with his right hand. When he looked for the lab assistant's face, he was more accurate with his right hand and made no mistakes. Keenan and colleagues concluded that the right hemisphere is more sensitive to self-face recognition than the left hemisphere.

Keenan and colleagues drew the same conclusion from another study in which they used patients undergoing intracarotid amobarbital procedure (or Wada test). This test consists in anaesthetizing one cerebral hemisphere at a time to assess cerebral dominance of various cognitive functions before a surgical treatment of epilepsy. During this Wada test, 5 patients were shown a picture of their own face morphed with a celebrity's face and asked to remember this picture. After they recovered from the anaesthetization they were shown the two original pictures (i.e., their own face and the famous face) and had to choose the one that has been presented beforehand. When the left hemisphere had been inactivated and that only the right hemisphere was still active, all 5 patients chose their own face. When the right hemisphere had been inactivated, 4 out of the 5 patients chose the famous face. In addition, similar results were found with healthy participants treated with TMS. The authors concluded that "it is conceivable that a right-hemisphere network gives rise to self-awareness, which may be a hallmark of higher-order consciousness" (p. 305).

Finally, a study using another split-brain patient, JW, has however led to opposite conclusions (Turk et al., 2002). As in Keenan, Wheeler, Platek, et al. (2003)'s study, the patient face was morphed with other faces in order to obtain 11 morphs ranging from 0 to 100 %. However, these other faces were those of two personally familiar people (one of the patient's doctors - Michael Gazzaniga - and one of his associates). Here, the pictures were also presented in a random order but they were shown laterally to each hemisphere (the response hand however is not mentioned in the paper). JW was instructed to judge if the picture depicted himself in one condition or MG in the other condition. Results showed that both of JW's hemispheres were capable of self-recognition. However, the right hemisphere preferentially recognised the other familiar face while the left hemisphere preferentially recognised the self-face.

These studies involving split-brain patients reviewed above can not bring consensus as to the lateralisation of self-face recognition. It is always difficult to generalise findings resulting from the examination of one or couples of patients, but it is even more puzzling when different studies lead to different conclusions. Moreover, one might have noted that the procedures used to present the stimuli to one cerebral hemisphere at a time, or to involve one cerebral hemisphere at a time during patients' responses were different across all these studies. They have used various combinations of lateralised versus central presentation and different response-hands. This might not help in finding converging evidence.

Hemispheric biases for self-face recognition have also been studied with rTMS. This technique allows the demonstration of causal relationships between neural regions and self-recognition. Indeed, virtual lesions can be created in chosen regions and effects of this manipulation can be compared to an absence of manipulation. Uddin et al. (2006) found that the right inferior parietal lobule is implicated during self-face recognition. They used a low-frequency repetitive transcranial magnetic stimulation to inhibit activity of this region and found that this manipulation decreased the sensitivity of participants to detect their own face among morphed images of themselves and another highly familiar person. This manipulation had no effect when it was applied on the same region on the left side.

Implication of the right hemisphere has been found in another study using TMS (Théoret et al., 2004). However, in this case, the presentation of the self-face was compared with the presentation of unfamiliar faces.

Electrophysiological and functional neurorimaging data

All the studies reviewed so far furnished information merely about lateralisation of self-face processing. Other techniques have been used to obtain more precise understanding of the anatomical location (e.g., with functional magnetic resonance imaging -fMRI-, positron emission tomography -PET scan-, or event-related potentials -ERPs- acquired with electroencephalography recording) or of the time course (e.g., with ERPs) of visual self-recognition.

Self-face – Keenan and Platek's group has conducted two fMRI studies in order to directly specify regions of the right hemisphere that are implied during self-face recognition. In the first study (Platek, Keenan, Gallup, & Mohamed, 2004), participants were presented with their own face or with famous faces and were instructed to think about the person depicted on the pictures (in other words, no behavioural data was available, see Section 4.3. of Chapter 1, for a discussion of this point). This task elicited activity in the right superior, middle and inferior frontal gyri when the self-face was presented by comparison with a famous face. Moreover, in order to test their hypothesis that self-face recognition is linked to other higher-order capacities such as theory of mind (see Keenan, Gallup, et al., 2003; Keenan, Wheeler, et al., 2000), participants had to perform another task of mental state attribution. They were presented with individuals' faces whose eyes expressed various mental states and had to think about the mental state of the person depicted. This task revealed activity in the medial superior frontal gyrus, in the right middle and superior frontal gyri. Activity was also found in the left hemisphere, more specifically in the middle frontal gyrus and in the superior temporal gyrus/pole. They concluded that right middle and superior frontal gyri are implicated in both tasks and therefore that self-awareness and theory of mind are subtended by the same neural network within the right hemisphere (but see objections raised by Morin, 2002, 2007, presented in Section 4.3. of Chapter 1).

In their second study carried out two years later (Platek et al., 2006), more rigorous control of familiarity effects was introduced by comparing the self-face both to unknown faces and personally familiar faces. Participants had to perform an identity judgment on these three kinds of faces. A baseline condition in which a scrambled face was presented was also included. When the self-face condition was compared to the familiar face condition, implications of the medial frontal and inferior parietal lobes, and superior frontal gyrus on the right, and of the middle temporal gyrus on the left were found. The familiar face elicited activation in the left anterior cingulate gyrus by comparison with the self-face. The authors acknowledge (p. 96) that their "results may be used to reconcile the left and right hemisphere models of self-awareness and supports a more complex bilateral network (Kircher et al., 2001) for both perceptual and executive aspects of self-face processing that cannot be reduced to a simplistic hemispheric dominance model".

This vision of a complex bilateral network subtending self-face recognition has at first been advocated by another group (Kircher et al., 2000, 2001). This group conducted an fMRI study in order to determine the neural correlates of self-processing (Kircher et al., 2000; see also Kircher et al., 2001). More specifically, they examined whether distinct cerebral areas were involved in self versus non-self processing and whether these regions were implied independently of the material. They presented male participants with their own face morphed with an unfamiliar male face in a first experiment. In a second experiment, male participants saw their female partner's faces morphed with an unfamiliar female face. In both cases, they were instructed to indicate whether the face was familiar (i.e., own face or partner's face) or unfamiliar. The self versus unknown contrast showed activation mainly in the right limbic system reflecting an emotional response and in the left prefrontal cortex reflecting an integrative process. The left inferior parietal lobe and cerebellum were also implicated. The partner's face elicited activity in the right anterior insula which might also reflect an emotional response. Finally, in a third experiment participants had to judge adjectives as self-descriptive or non-self-descriptive. Self-descriptive adjective were judged faster than non-self-descriptive adjectives, suggesting that the self-concept is stable and that a good self-knowledge allowed these quick answers. These self-descriptive adjectives triggered activity mainly in the left hemisphere (i.e., left parietal lobe, insula, inferior frontal gyrus and anterior cingulate) and in the bilateral precuneus, corresponding to the processing of a verbal material and recourse to personal semantic knowledge.

In addition, they have examined common regions implicated in both kinds of self-processes. These regions were the left fusiform gyrus and precuneus, as well as the right lingual gyrus and insula. The authors conclude that explicit self-recognition is subtended by a complex integrative neural network in which three components are active simultaneously: sensorial inputs (to update one's own face representation), memory (furnishing the feeling of continuity essential to the sense of self) and an emotional component (giving rise to feeling of familiarity and of coherence necessary to the sense of self).

In a PET study, Sugiura et al. (2000) have also investigated self-recognition correlates. They used three different tasks each involving faces tilted to the right or to the left and participants had to judge the orientation of the faces. In the control task, faces were all unfamiliar. In the passive recognition task, the self-face was presented on some trials. Finally, in an active recognition task, participants had to indicate when their own face was presented in addition to the orientation task. Skin conductance was also measured and it appeared to be enhanced in both conditions where the self-face was presented. The left fusiform gyrus and the right supramarginal gyrus were activated during these two conditions of passive and active recognition of the self-face. According to the authors, this suggests that these regions subtend the representation of the self-face. The left putamen and the right hypothalamus were also implicated during both conditions. Moreover, regarding the active recognition condition by comparison with the two others, it elicited activity in the right anterior cingulate, the right presupplementary motor area, the prefrontal cortices and the left insula. The authors claim that this is an indication that these areas are involved in the sustained attention to the representation of the self-face. However, their study did not include familiar faces as control and it is possible that these areas are merely implicated in familiarity processing and not specifically in self-face processing.

The same team corrected this flaw in a subsequent study (Sugiura et al., 2005). Indeed, they carried out an fMRI study aimed at identifying the cortical mechanisms of self-face recognition and controlled the selectivity of the activation for the self-face. They compared the activity elicited by the self-face to that triggered by faces of different familiarity (i.e., a prelearned unfamiliar face, an experimenter's face, and a friend's face). They excluded activation that could be explained by these differences of familiarity. They found that the right occipito-temporo-parietal junction and frontal operculum, and that the left fusiform gyrus are selectively implied in self-face recognition.

In a last (to date and to our knowledge) self-face recognition study using fMRI, Uddin, Kaplan, Molnar-Szakacs, Zaidel and Iacoboni (2005) showed that a neural network in the right hemisphere including the inferior frontal gyrus and the inferior parietal lobule is implicated during self-face recognition. To demonstrate this, they used pictures of their participants' own face that had been morphed by steps of 20% with another personally familiar face. There were thus 6 different pictures (two originals and 4 intermediate, so that there was no 50-50% morph) that were presented in random order. The pictures sequences also contained a scramble control picture. Participants were instructed to press a button if the picture looked like themselves and another one if it looked like another or scrambled face. The other highly familiar face elicited more activity than the self-face in the precuneus and medial prefrontal cortex.

Finally, a couple of studies have used ERPs to investigate specificity of self-face processing. Ninomiya, Onitsuka, Chen, Sato and Tashiro (1998) have shown that one's own face is an emotionally salient stimulus. Indeed, their participants presented a more ample P300 (at Cz electrode) when they were unexpectedly presented with their own face than when they saw other familiar faces or a red square. In another study, Sui et al. (2006) showed that the self-face and other faces were not yet differentiated on early components such as N170, reflecting structural encoding of faces. However, self-face was differentiated from familiar faces from latencies around 220 ms in that they elicited more ample positive wave in the frontocentral area whereas familiar faces did not differ from unfamiliar faces. Moreover, the self-face effect was independent of the task at hand (i.e., whether or not it had to be attended) which was not the case for familiar faces. According to Sui et al., this suggests that self-face recognition is subtended by unique mechanisms, contrary to other faces. These results contrast with those of another study (Keyes & Brady, 2007) showing that self-face can already be differentiated from other familiar or unfamiliar faces on N170 component. Marginal effects of the familiar face by comparison with the unfamiliar face were only observed later. The authors suggest that the brain could differentiate faces according to self versus non-self dimension before categorising them according to familiarity.

All these studies thus bring various results. They do not all permit to firmly conclude that the reported activations are really self-face specific since some of them did not include familiar faces as control for simple familiarity effect. It is only quite recently that these controls begin to be more systematically included. As Gillihan and Farah (2005) argued in their review (p. 80), “a clear pattern of anatomical localization has yet to emerge for self-face recognition”. They carefully (and wisely) concluded that “at the present time the most one can say with confidence is that both hemispheres probably participate to some degree but that right prefrontal areas may be particularly important”.

Self-body – Only very recently, some studies started to examine the neural correlates of one’s own body-shape recognition. Previous studies had already examined various questions related to the self-body processing (e.g., agency and perspective taking, see Farrer et al., 2003; Farrer & Frith, 2002; Farrer, Passingham, & Frith, 2002; Newen & Vogeley, 2003; Ruby & Decety, 2001; Vogeley & Fink, 2003) but not directly as regard with its shape representation.

In one study using fMRI, Kurosaki, Shirao, Yamashita, Okamoto, & Yamawaki (2006) investigated gender differences during processing of pictures showing distorted self-body. The distortions consisted in enlarging (fat-body-image) or reducing (thin-body-image) the width of the whole body (including the head). Participants were presented with pairs of pictures (one original and one distorted) and were instructed to select the more unpleasant one. Each kind of distortion was presented in a separate block (fat-body-image task versus thin-body-image task). In a control condition (real-image task), the two same original pictures were presented but one of them was marked with a red cross. In that case, participants had to design on which side the marked picture had been presented. When they compared patterns of brain activation during altered-image tasks and real-image task, they found some brain activation differences between men and women. When seeing an altered version of the own-body, women presented activity in bilateral prefrontal cortices and in the left limbic (including amygdala, cingulate gyrus and insula) areas. Men rather showed activity in the right occipital cortex. According to the authors, this indicates that women seem to perceive distorted images of themselves by complex cognitivo-emotional processing. Attentional and self-monitoring processes would be implied when they perceive their distorted body (specifically the thin version). By contrast, a more visuo-spatial processing seems involved in men. However, these authors were interested in the processing of distorted images of oneself and they did not report data related to intact items. Moreover, self-body distorted pictures were compared to self-body intact pictures. So it is impossible to know whether these activations and gender differences really reflect self-body processing per se or just more general body-shape evaluative judgments. Finally, their body stimuli included the heads. So it is also difficult to know whether the observed effects are really body specific or if they are partly due to faces.

In another study, Sugiura et al. (2006) were interested in the question of whether different neural networks subtend different forms of visual self-recognition. They hypothesised that a first network including the left fusiform gyrus might be involved during processing of self-image as a symbol and as a consequence should be implied during the presentation of static pictures of the self-face. A second network formed by the right frontal and parietal cortices might be implied during the processing of motion-action contingencies. This network should thus be sensitive to presentation of movies showing the whole self-body. To test their hypothesis, they presented their participants with four types of stimuli: static images depicting faces or whole bodies presenting various configurations, and movies showing faces or bodies performing various actions. Moreover, each of these stimulus types showed either the participant him/herself, another familiar person (i.e. a friend), or an unfamiliar person. Participants had to perform a familiarity judgments on these stimuli (i.e., categorise self and friend as “familiar” and the unknown person as “unfamiliar”). Self versus friend contrast collapsed across the four conditions revealed implication of a bilateral ventral occipito-temporal region extending over the fusiform gyrus and of the right parietal and frontal cortices. Consistent with their hypothesis, the left ventral occipito-temporal cortex was more active during self-face than during self-body perception (however, this was only true for pictures). The hypothesis that the fusiform gyrus processes the self-face as a symbol was thus confirmed. However, their second hypothesis was not supported by the results showing right parietal and frontal cortices implication but no preferential activation in these regions for movies of bodies. The results nonetheless support the idea of the existence of multiple brain networks for visual self-recognition.

Finally, two other studies interested in the effect of viewpoints and perspective on body representation have to be mentioned even if they are a bit more removed from our specific field of interest (Chan, Peelen, & Downing, 2004; Saxe, Jamal, & Powell, 2006). They were both examining whether the extrastriate body area (EBA) that has been shown to be specifically involved during processing of bodily stimuli can differentiate egocentric and allocentric views of bodies. In the first study (Chan et al., 2004), various body parts (excluding the head) of participants were photographed both from an allocentric (i.e. as seen by other people) and from an egocentric perspective (i.e., as seen by oneself; these pictures were taken by placing the camera in front of participants' eyes). Each participant was presented with the pictures of his/her own body and with those of four other personally familiar persons. Participants had to perform a 1-back repetition-detection task (report whenever two identical images appeared consecutively). Results showed that the right EBA was more active during presentation of allocentric than during egocentric views while there was no difference in the left EBA. This suggests that the right EBA might be tuned towards the processing of others. By contrast, the identity had no effect on the activation of the EBA, suggesting that this structure is involved in early stages of social vision. The authors report other bilateral regions (anterior superior temporal sulcus among others) were more active during processing of others that during processing of the self. Unfortunately they do not report results as to the reverse contrast. The left superior parietal cortex was more implicated in processing of egocentric than of allocentric views, but irrespectively of the identity.

In the second study (Saxe et al., 2006), participants saw pictures of hands, arms, legs and feet that had been photographed from an egocentric and from an allocentric view (here defined as a view inaccessible from the body's owner viewpoint). However, these pictures were taken from a model unfamiliar to the participants. As in the previous experiment, participants performed a 1-back repetition-detection task. Consistently with Chan and colleagues (2004)' results, the right EBA was more active when viewing allocentric views than when viewing egocentric views. By contrast, the left post-central gyrus and the right dorsolateral prefrontal cortex were more active when viewing egocentric view by comparison with allocentric views.

In sum, neural correlates of one's own body-shape representation per se have not yet been documented much. Only a couple of studies have begun to examine various processing in direct relation with one's own body appearance. Sugiura et al. (2006)'s study suggest that different self-related features are processed by different cerebral networks. However, neural correlates of self-body shape still have to be defined. At present, very little can be concluded from specific activations found for egocentric viewpoints since they were independent of body identity (Chan et al., 2004). These activations might in fact have more to do with ownership and other kind of self-processing than with visual self-recognition.

To date, it seems that no study has simultaneously examined neural correlates of self-face and self-body recognition except Sugiura et al. (2006)'s study. However, these authors examined whether *different* neural correlates could be identified depending of the kind of visual self-related stimulus that was presented. Apparently, it has not yet been assessed whether some *integrative* cerebral areas could differentiate self-recognition from other person recognition *independently* of the type of visual stimulus presented. This is what we will attempt to do in Chapter 5.

3.2. Other self-referential stimuli

A high number of studies have examined neural correlates subtending the processing of other kind of self-referential stimuli. We do not have sufficient space to detail all these studies here. Therefore we will only describe briefly some of these studies and see whether some trends can be extracted as to the neural correlates subtending processing of self-related stimuli (for more exhaustive reviews, see Gillihan & Farah, 2005; Gusnard, 2005; Northoff & Bermphol, 2004).

The own name has often been used as stimulus in electrophysiological or functional neuroimaging studies. For instance, a recent fMRi (Carmody & Lewis, 2006) study has shown that hearing one's own name elicited activation mainly in the left hemisphere (middle frontal cortex, cuneus and superior and middle temporal cortex by comparison with hearing four other names (Dan, Saul, Jay and Mike). However, as the names with which the own names were contrasted were unspecified in terms of familiarity, it is impossible to conclude whether these activations are self-specific or rather due to the familiarity of one's own name. In a combined PET and ERPs study, Perrin et al. (2005) found that the amplitude of the P3 component was more correlated with cerebral blood changes in the medial prefrontal cortex when participants heard their own name than when they heard other names. However, the PET data alone did not reveal any difference between the brain activity elicited by the presentation of the own name and that elicited by the presentation of other names. Moreover, the control names had been selected not to be the same as relatives and friends of participants. As a consequence, here also it is not possible to disentangle self effects from familiarity effects. Note that this is often the case that familiar control names are not used in studies using one’s own name, especially in non-communicative patient studies. Indeed, the own name is used as a salient stimulus to enhance chances of eliciting responses in these patients (see for instance Perrin et al., 2006; for a review see Laureys, Perrin, & Brédart, 2007; see also Section 5.2. of Chapter 1).

Recently, Miyakoshi, Nomura, and Ohira (2007) investigated processing time course and neural correlates of self-related objects recognition using ERPs. They presented participants with pictures of 4 objects (bag, shoes, cup and umbrella) that was either their own, either familiar (i.e. public or disposable) or unfamiliar (belonging to other persons). The objects were not differentiated according to their relative familiarity before 250 ms after stimulus onset. The N250 component differentiated self and familiar from unfamiliar objects in left occipitotemporal area. Self-related objects were differentiated from familiar objects later, from 300 ms in frontal, parietal and temporal sites without clear lateralization. This indicates that self-relevance is processed by higher cognitive functions during object recognition.

Most studies interested in neural correlates of self-processing have used psychological self-referential stimuli. In these studies, neural activity of participants was examined while they were judging items in reference with their own traits (for instance adjectives, see Craik et al., 1999; Kelley et al., 2002; Kircher et al., 2002; or sentences, Johnson et al., 2002) or preferences (Seger, Stone, & Keenan, 2004). Various neural regions in both hemispheres have been found to play a role during these processes. An fMRI study contrasting self-referential judgments of adjectives and semantic judments of adjectives revealed implication of the right dorsomedial prefrontal cortex (Fossati et al., 2003). In a similar study, the medial prefrontal and posterior cingulate cortices were implicated during judgment of sentence as self-descriptive by comparison with judgment of sentences as semantically accurate

(Johnson et al., 2002). In another fMRI study implicating trait adjectives (Kircher el al., 2002), participants judged these adjectives as self- or non-self-descriptive in one experiment (intentional self processing) or performed a semantic judgment on these adjectives that had been classified according to their self descriptiveness (incidental self processing). Two regions of the left hemisphere (superior parietal lobule and fusiform gyrus) were commonly implicated in both types of self-processing. In these three studies however, there was no adequate control situation allowing the conclusion that activated brain regions are specifically recruited by the self-referential component of the processing.

In another study, specific activation of the right anterior cingulate has been found when comparing self-referential encoding to semantic encoding. However, in line with our previous comment, no differential activation was found when contrasting self-referential encoding to other-referential (i.e. pertaining to a famous person) encoding (Craik et al., 1999). Implication of the ventromedial prefrontal cortex was nonetheless found in a study where participants were asked to reflect on their own traits when this task was contrasted with a situation where participants reflected on other persons (i.e. celebrities)' traits (D'Argembeau et al., 2005). Moreover, this region was also implicated in a resting state situation suggesting that self-referential reflective activity might be an important component of the resting state. The medial prefrontal cortex was also implied when comparing self-referential judgment to other-referential (i.e., pertaining to George Bush) judgment in another fMRI study (Kelley et al., 2002). Finally, it has been shown that medial parietal areas seem recruited during judgments about one's own food preferences versus judgments about someone else's (a roommate or a friend) preferences (Seger et al., 2004).

As the brief overview of these studies shows, it is still difficult to interpret data to date in favour of the existence of a specific neural network devoted to the processing of self-referential stimuli. Self-referential processing has often been compared to other kind of processing differing in various dimensions other than just the self aspect (semantic judgment for instance). When control conditions implied other persons, they were commonly celebrities. Therefore differing brain responses might reflect differing amount of knowledge about the self and these persons or differential affective responses to these two types of stimulus (see Gillihan & Farah, 2005).

3.4. Conclusion

We have seen throughout this section that interest of the neuroscientific community in neural correlates of self-referential processing is growing exponentially. This realm of research is still in its infancy and it appears difficult to date to extract clear invariant conclusions from existing data. A trend that could be extracted from visual self-face recognition is that both hemispheres are implied but with the right prefrontal cortex being preferentially involved (Gillihan & Farah, 2005). Data relative to visual self-body processing is still insufficient to conclude much except that this type of processing might involve a different cerebral network by comparison with self-face processing (Sugiura et al., 2006).

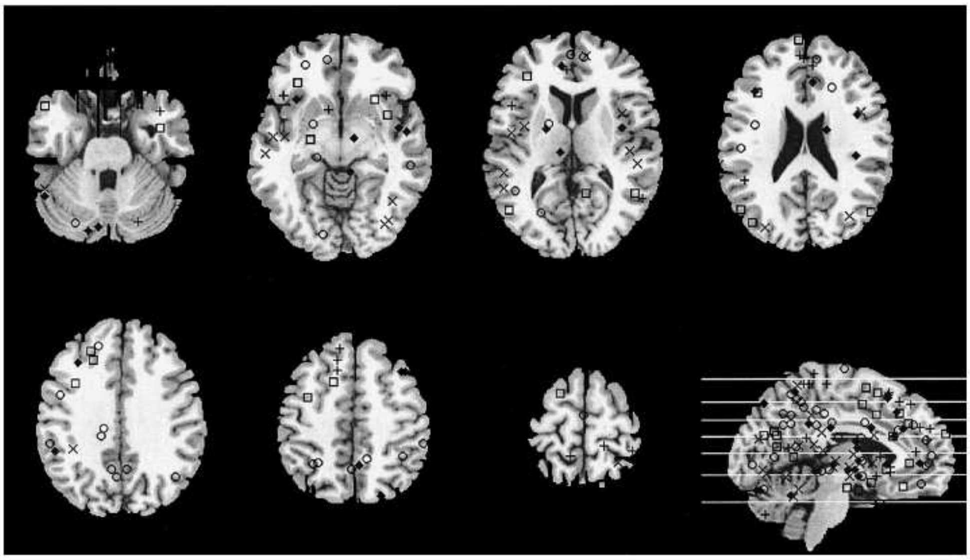

Figure 6. Brain regions reported to be more active during self-related processing across multiple domains, collapsed across studies within domain (e.g., traits). Activation foci are shown in axial slices of the standard Montreal Neurological Institute brain (right is right), taken at the levels shown in the sagittal slice. The symbols represent the center of these activations according to the Talaraich coordinates provided by the authors and do not show the volume of activation. The sagittal view shows these symbols in "glass brain" view, such that all areas of activation are visible regardless of whether they fall on the midline. Symbols correspond as follows: ◆ = face; × = agency; ○ = traits; □ = memory; + = first-person perspective.

Figure 1. Summary figure of all brain areas implicated during self-processing (From Gillihan & Farah, 2005).

It has also been suggested from existing data implicating various kinds of self-referential stimuli that both hemispheres (see Morin, 2003) and more particularly medial regions (specifically the medial prefrontal cortex) might play a crucial role in their processing (Gusnard, 2005; Northoff & Bermphol, 2004) along with the parietal cortices (Gusnard, 2005). However, differential regions seem implicated as a function of the task at hand and of the type of self-referential stimulus involved. Figure 1 illustrates how much too drastic conclusions should not be drawn about specific and precise neural correlates of self-processing since areas covering almost the whole brain have been found to be implicated during various types of self-processing.

The question we asked in this chapter concerned the specificity of self-referential stimuli by comparison with other types of stimuli. As others (Gillihan & Farah, 2005), we think that a positive answer to this question in terms of neural correlates would be premature. Indeed, existing studies only rarely used adequate controls of confounding factors such as familiarity, emotional salience and so on when comparing self-processing to other kinds of processing (see Gillihan & Farah, 2005). Hopefully, people are more and more sensitive to these aspects and a clearer answer to that fascinating question should emerge in a near future.

4. Attentional properties

After having questioned specificity of self-referential stimuli as regard with their representations in memory and their neural correlates, we will examine whether they possess special properties favouring their selection by attention. Before going further and examine results of studies using self-referential stimuli, we need to describe the context in which they have been conducted.

4.1. Important stimuli and theories of attention

Once we are awake we are constantly receiving an incessant flow of external and internal perceptual information. In order to perceive our environment coherently and to behave in an adapted way, we need to sort all these incoming sensory information. This is accomplished thanks to the mechanism of selective attention. Because our attentional abilities are limited (see Pashler & Johnston, 1998), this mechanism selects high-priority stimuli to be processed in accordance with our current goals while in the meantime ignores other goal-irrelevant stimuli (for a review see Driver, 2001). Psychologists and more recently neuroscientists have investigated for a long time the extent to which certain salient and significant stimuli possess the property of being preferentially selected by attention by comparison with less important stimuli. Typically, researchers have investigated whether such stimuli are processed when they are supposedly unattended (e.g., when they are presented outside the focus of attention) by measuring their reportability or the interference they produced on the processing of other target stimuli. Self-referential stimuli such as one's own name have often been used in order to examine these questions. This was a clear-cut way to have an important, personally relevant and easily constructible stimulus tailored to each individual subject.

The impact of the outcomes of these studies would be significant for the theorisation of attention because of the lengthy debate between the defenders of an early selection of attention and the defenders of a late selection theory of attention. For the former, the attentional selection concerns the gross stimulus features at an early stage of processing (Broadbent, 1958). This view therefore implies severe limitations in perceptual processing (Pashler & Johnston, 1998). For instance, Broadbent (1958)'s Filter Theory assumed that we are only able to identify one spoken word at a time. By contrast, the latter theory of late selection of attention argues that the attentional selection takes place after a complete semantic processing of all incoming information (Deutsch & Deutsch, 1963). This view thus presupposes virtually no limitation in sensory and perceptual processes. It is based on evidence showing that some stimuli have been analysed semantically whereas participants had made some effort to ignore them (see Pashler & Johnston, 1998).

As a consequence, evidence of interference created by supposedly unattended self-referential stimuli on the performance on the ongoing task would rather support the late selection theory of attention, whereas an absence of interference would rather be in support of the early selection theory. However, things are not that simple[4], since to date these studies have brought different outcomes and some discrepancies appeared in their respective conclusions. These studies and their results are overviewed below.

4.2. Evidence in favour of an attentional specificity of self-referential stimuli

Since the late fifties, self-referential stimuli have been described as particularly prone to grab attention by comparison with other stimuli. This claim emerged from the famous study by Moray (1959) using the method of shadowing (see Cherry, 1953) during a dichotic listening task. This method involves the presentation of two different messages to each ear by means of earphones. Participants are instructed to focus on the message presented to one ear and to repeat it aloud (i.e., shadow) while ignoring the message presented to the other ear. While a short list of neutral words presented many times to the unattended ear showed no trace of being remembered (replicating Cherry's findings), Moray (1959) found that 4 participants out of 12 (33%) remembered that they had heard their own name at its first presentation to the unattended ear. Moray called this effect the "identification paradox" since the own name, because of its importance, appeared to be able to pass through the attentional filter whereas the verbal content of the other less important to-be-rejected stimuli was blocked. To Moray, his findings indicated that "the block in dichotic shadowing occurs at quite high level" (p. 59) and his findings are probably one of the first in favour of the late selection theory. However, these results have later been questioned as there was no way to exclude the possibility that subjects shifted their attention from time to time to the to-be-ignore message, hence actually attending to it and therefore perceiving it (see Lachter, Forster, & Ruthruff, 2004, that confirmed this criticism using a priming paradigm). Nonetheless, Wood and Cowan (1995) recently replicated Moray's results with more careful control of temporal lapses of attention.

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[4] Corollary, there are intermediate theories in between the two extreme views defended by the late selection and early selection theories of attention - see for instance the Treisman (1960)'s attenuation theory or the Treisman and Gelade (1980)' feature integration theory.

Since then, evidence for some “own name effects” has also been found in other studies using various procedures. Wolford and Morrison (1980) designed what they called a visual analogous of the Moray’s procedure. In their task, they presented their participants with two peripheral digits flanking a central to-be-ignored word. Participants were instructed to make a parity judgment on the two digits. On most trials (i.e. 116 out of 120), the central words were neutral words and on four time-spaced trials they were the participant’s own name. Neutral words did not cause distraction as they produced similar reaction times and accuracy by comparison with a control situation where no word was presented centrally between the two target digits. However, results showed that the presence of participant’s own name affected response times (but not the accuracy) by comparison with neutral words. Moreover, 80% of participants reported subsequently that they had seen their own name whereas they recognized only 68% of words presented the same number of times during the experiment. According to the authors, their results argue in favour of a robust name effect (but see Bundesen, Kyllingsbaek, Houmann, & Jensen, 1997; Harris & Pashler, 2004). However, given the central position of the to-be-ignored stimuli they were located within the focus of attention and were presumably attended preventing any strong conclusion in favour of a late selection theory of attention.

In two studies involving rapid serial visual presentation (RSVP) Shapiro’s group presented evidence in favour of a late selection theory by showing that the own name was more resistant than other words to two attentional limitation effects (i.e. attentional blink and repetition blindness). The attentional blink (AB) arises when after having identified a first target (target 1, e.g. a white letter) in a RSVP (e.g. composed of black letter) participants fail to detect the presence of a probe (target 2, e.g. the black letter “x”) that has been presented within a certain temporal window after target 1 (i.e., up to 500 ms). In a set of experiments aimed at accounting for AB effects, Shapiro and colleagues (Shapiro, Caldwell, & Sorensen, 1997) found that when the probe was the participant’s own name and that it was presented in a stream of names, it resisted more to AB than other names or nouns. This suggests that certain stimuli have a lower detection/activation threshold and thus a higher salience than others. As a consequence they would suffer less interference when competing with other stimuli. However, when the target and the probe were presented in a stream of nouns, other names were also more resistant to AB than nouns. This suggests that the salience of certain stimuli such as other names might be dependent upon the distractor stream whereas one's own name is even more salient, which allows its detection regardless of the distractor stream.

In another study, this same team (Arnell, Shapiro, & Sorensen, 1999) investigated repetition blindness (RB). When two identical stimuli are presented in a RSVP paradigm, RB is said to occur if participants that accurately detected the first instance of the stimulus fail to detect the second occurrence of the stimulus. This seems to be a robust effect occurring as far as the two stimuli share similar properties as regard with their visual identity, phonology or even possibly meaning. Arnell et al. thus compared RB for one's own name and other names to examine whether RB can be modulated by the lexical/conceptual (i.e. processed at a relatively late stages) representation of a stimulus. They found RB in the "other name" condition as well as in the "own name condition". RB however was reduced for the own name.

In 1998, Mack and Rock designed a paradigm aimed at assessing whether a stimulus can be perceived without attention. In this paradigm, an unexpected stimulus is presented in the visual field of an observer while his attention is focused on another task. Observers are instructed to perform a length judgment task on a cross presented very briefly. This procedure is used during two or three trials (i.e., non-critical trials). Then, on the third or fourth trial (i.e., critical trial), a critical stimulus is unexpectedly presented besides the big cross. Immediately after the length judgment, observers are asked whether they have seen something besides the big cross that was not present before. Then they are asked to describe it or to pick it up in a set of alternatives.

Inattentional blindness (IB) occurs when observers fail to detect the critical stimulus. Simple geometrical shapes produce IB rates up to 85%. According to Mack and Rock, this suggests that perception requires attention and that attention must first be captured before perception can occur. They then examined whether certain important stimuli are particularly prone to capture attention. They found that the own name was more resistant to IB than other stimuli (another name or some of the most frequent words in the English language such as "House" or "Time") and concluded that the own name does capture attention because of its importance (rather than because of its lexicality or familiarity). To support their claim, they carried out further experiments in which an alteration was made to the participant's name by replacing the first vowel with another and found that the detection rates were then highly reduced. They argued that these results were in favour of a late selection theory (Deutsch & Deutsch, 1963) in which attention is captured at a late stage of the visual processing when the meaning is already available. Indeed, their results indicate that the own name does not capture attention because of its gross perceptual features (as an early selection of attention theory would have predicted, see Broadbent, 1958) since a modest alteration of its features has such a huge effect on its attention-grabbing capacity. In other experiments, they found similar results with other salient stimuli such as happy face icons.

Later, Shelley-Tremblay and Mack (1999) showed that the own name and happy face icons were more resistant to backward metacontrast masking than other stimuli (i.e. scrambled own name, the word "time"; or scrambled and inverted faces, respectively). This phenomenon consists in a reduced or even eliminated visibility of a briefly presented stimulus when it is followed by a surrounding or flanking other stimulus (i.e. mask). The own name was also a more potent mask than a scramble variant or the word "time". More recently, Mack, Pappas, Silverman, and Gay (2002) confirmed the finding that one's own name or a happy face icon capture attention because of their importance and high signal value using three different paradigms (IB, attentional blink, and stimulus crowding). Moreover, using a visual search task Mack and Rock (1998) also showed that, contrary to other names, the own name pops out of a display of up to 12 items (but see Harris, Pashler, & Coburn, 2004).

In sum, all these results seem in favour of a late selection theory of attention (Deutsch & Deutsch, 1963), since they suggest that the meaning and significance of some stimuli can determine their selection by attention. However, all of these studies used the own name as the example of a highly salient stimulus. Yet our name (our first name as well as our last name) is a property that we usually share with other people. It is thus possible that the abovementioned effects are mediated by some lower level effects (i.e., merely due to one's own name high familiarity) calling into question the conclusion of these studies.

The self-face has the advantage that it is a unique self-referential characteristic (with the exception of twins). Therefore, it constitutes an ideal way to investigate the attentional specificity of self-referential stimuli and more generally of significant stimuli. However, only few studies to date (Brédart, Delchambre, & Laureys, 2006; Laarni et al., 2000; Ninomiya et al., 1998; Tong & Nakayama, 1999) have used it in this context. Note however that here again an adequate stimulus of comparison is mandatory to allow the claim that possible effects are due to the self aspect (in other words to its significance and meaning) of the self-face.

Recently, Brédart et al. (2006) used a face-name interference paradigm in order to assess whether the self-face is harder to ignore than other familiar faces. They presented their participants with central names flanked by a face. The names were either the participant's own name or name of another familiar person (i.e. a classmate). The flanking faces were three different familiar faces: the self-face, the classmate's face or the face of a participants' professor. Participants were instructed to classify the names as their own or as their classmate's name and to ignore the faces (that presentations were congruent or incongruent as regard with the to-be-processed names). Results showed that the self-face flanking a classmate's name produced a stronger interference on the processing of this name than classmate's face flanking the participant's own name. This effect was not due to a particular resistance of the own name to facial interference since both the own name and the classmate's name were subjects to a similar interference resulting from the presentation of the professor's face. This suggests that the self-face has some attention-grabbing capacity resulting from its particular emotional value or its high familiarity.

In a visual search task that we already mentioned (see Section 2.1. above), Tong and Nakayama (1999) demonstrated that the self-face was more quickly detected among distractors than strangers' faces even when presented in atypical orientations and after hundreds of trials. Moreover, participants were quicker at rejecting their own face as distractor than other faces. All these findings thus suggest that important stimuli benefit from specific attention-grabbing capacities, which is in favour of a late selection theory of attention (Deutsch & Deutsch, 1963). However, this last study as many others presented above (with the exception of the Brédart et al. 2006's study that purposely used highly familiar control faces and of Mack and Rock's huge work attempting at rejecting familiarity accounts of their own name effects) used neutral and unfamiliar control items. For this reason many of these results may just reflect some familiarity effects rather than genuine "self-effects". This is an important limitation because it might in turn suggest that the selection of attention does not occur at a so late stage of processing as had been thought.

4.3. Evidence against an attentional specificity of self-referential stimuli

Other researches have seriously questioned this view of the specificity of the own name and face by suggesting that self-referential stimuli do not benefit from particular attention-grabbing capacities. Ten years ago, a study by Bundesen, Kyllingsbæk, Houmann, and Jensen (1997) challenged previous findings by showing that one's own name does not attract attention more than other stimuli. Their study was based on work by Schneider and Shiffrin in late seventies (see Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) showing that an automatic attention attraction by alphanumeric characters can develop in some conditions. In Shiffrin and Schneider (1977)'s study (Experiment 4d), participants underwent an extensive training phase in which they had to detect target digits while ignoring distractor letters. Then, in a subsequent task, they had to judge whether two targets letters were presented among a display composed of a 4 letters-matrix. The two target letters always appeared on the same diagonal line and so the two other distractor letters were to be ignored as they always appeared on an irrelevant location. Nonetheless, participants were distracted by the presentation of two digits (i.e., previous targets) at these irrelevant locations.

In order to assess whether more complex stimuli such as words can also automatically attract attention, Bundesen et al. (1997) used briefly (i.e. 150 ms) presented masked displays composed of four names, two red-coloured (targets to be reported) and two white-coloured (distractors to be ignored). The participant's name was presented on some trials, either as target or as distractor. They found that participants were more accurate in reporting their own name presented as targets (i.e. 67% of correct reports) than in reporting targets from display without their own name (i.e. 57% of correct reports). However, the own name presented as distractor did not cause more interference than other distractor names since the reports of the targets were virtually the same in both cases (i.e. 56% and 57% of correct reports respectively). This suggests that the own name does not automatically attract attention. Moreover, Bundesen et al. hypothesised that the advantage found for the own name when it was a target by comparison with other target names was not attentional but merely reflect a sensitivity effect. They thus conducted a control experiment in which participants had to identify single names presented very briefly (i.e. 83 ms). They found that participants identified their own name more accurately (i.e. 73%) than other names (i.e. 46%) indicating that participants were simply better at identifying their own name than other names. Finally Bundesen et al. explain the contrast between their findings with multi-letter words and those with single alphanumeric characters by the relative complexity of these stimuli and argue that complex stimuli can not attract visual attention.

Consistently, in another study using faces, Laarni et al. (2000) presented their participants with pairs of faces that they had to match. The background was composed of a matrix of faces that they had to ignore. Participants' own face or a celebrity face (the Finnish President) was presented on some trials (i.e. critical trials). Results showed that only 18% of participants reported that they had seen their own face during the task and the performance was similar for both familiar faces.

These results could be interpreted in terms of an early selection of attention occurring at an early stage of processing (Broadbent, 1958). Indeed they suggest that significant stimuli are not processed further when they have already been discarded from the perceptual process by the properties of their low level features (e.g. irrelevant colour or irrelevant background location).

4.4. Compromise evidence

Finally, some studies using the own name moderated findings presented here above by showing that some "self-effect" can occur but only when specific conditions are fulfilled. For instance, Kawahara and Yamada (2004) replicated Bundesen et al. (1997)'s findings with Japanese participants in a first experiment and addressed other interesting points in four other experiments. In two experiments, they assessed two possible explanations raised by Bundesen et al. (1997) for their null effect. In one of these experiments, they reduced the difference of colour between targets (now pink instead of red) and distractors in order to reduce the efficiency of target selection. In the other experiment, they recruited participants whose name consisted in a single Japanese Kanji character in order to assess Bundesen et al. (1997)'s hypothesis that attention can only be attracted by individual characters. In both cases, they could not find evidence that the own name attracts attention.

In two subsequent experiments, they examined a potential explanation in terms of observer's set to this null effect. They hypothesised that the *input filter* the observer prepares to optimise his/her performance to a task could determine whether a specific feature of a stimulus will attract attention or not. For instance, in Bundesen et al.'s study and in their three previous experiments, it is possible that the own name did not attract attention because participants tuned their input filters to pass target red items explaining that the white items (and therefore the own name as distractor) were not processed. In these two subsequent experiments, they used an adapted version of the attentional blink paradigm and showed, in line with the input filter hypothesis, that the own name only attracted attention when participants were set to identify target names whereas it did not when participants were set to find a target colour.

In another study, Gronau, Cohen, and Ben-Shakhar (2003) showed that the location of the own name within or outside the observer's focus of attention is also an important factor determining attention attraction. In a first experiment, they used a Stroop-like task in which participants were to name the colour of words presented centrally within the participant's attentional focus. On some trials, the coloured-word was a personally significant word tailored to each participant (i.e. his/her first name, his/her last name, his/her mother's name, his/her field of study). Results showed that in such a situation, the significant words attracted attention by comparison with neutral words (i.e. items from the same category but pertaining to another person). In a second experiment, the words were presented at periphery above or below a central coloured square. In this case, the interference caused by significant words was abolished. In a third experiment, the displays were identical to those of Experiment 2 but now the participants had to associate a significant word to each colour and had to utter this word in response to the coloured-square. Now, the peripheral words were processed as attested by a congruency effect. In other words, this suggests that when they were presented peripherally significant words attracted attention only when they were task relevant but not when they were task irrelevant. This is in line with the input filter hypothesis advanced by Kawahara and Yamada (2004).

Harris, Pashler, and Coburn (2004) also called Mack and Rock (1998)'s visual search findings into question by showing, in a set of 9 experiments, that even if the participant's own name was detected more rapidly than other names, it appeared to be subject to perceptual capacity limitations. Indeed, the search slopes they obtained were substantial and not flat enough to claim that the own name pops out and capture attention. Moreover, the own name had no more distractive power than other names. In other words, it was not a particularly powerful distractor as it did not hold participants' attention. Harris et al. note that their results actually echo those of Tong and Nakayama (1999) with the self-face. They interpret their results as a consequence of people's experience for searching their own name (see the notion of automatic attention attraction acquired through training developed by Schneider and Shiffrin and described above). Interestingly, they also showed that emotionally charged words did not particularly attract attention. However, this does not mean that the own name attracts attention more since it might just benefit from a training effect and that words might be weaker emotional stimuli than for instance emotionally charged pictures.

In another experiment based on the paradigm designed by Wolford and Morrison (1980, see Section 4.2. above), Harris and Pashler (2004) showed that the presentation of the own name could cause a distraction and slow down reaction times on a digit-parity task in comparison with neutral words, but only on condition that enough capacity is available. In this case however the distraction was only present during the first occurrences of the own name and the response quickly habituated. Moreover, the own name did not show special attention grabbing property anymore when display loads were more substantial and that the own name was presented among 6 other name stimuli. In addition, the surprise effect elicited by the own name was also found with emotionally charged words but to a lesser extent and only at their first occurrence. Taken together, this set of results suggests that the first occurrences of one's own name may provoke an involuntarily shift of attention when the perceptual load of one’s ongoing activity is low and enough capacity is available for one’s name to be perceived. However it rapidly loses its attention grabbing character. Hence, one’s own name is not a more potent distractor than other significant words.

4.5. Conclusion

In the realm of attention, self-referential stimuli have generally been used to assess divergent hypotheses and to elaborate theories of attention. In this context, researchers have mostly used the own name (and only recently the self-face) on basis of the assumption that it is a particularly salient stimulus because of its importance and significance for the participants. In other words, from the beginning and until lately, researchers have not really assessed whether self-referential stimuli are special but rather have used them as a tool to test different theories of attention. Only gradually has the interest in the specificity of self-referential stimuli emerged. At first glance, in this context it appeared logical to compare the own name (or face) to neutral, unfamiliar or unimportant stimuli. However, a lot of factors differentiate one’s own name or one’s own face from other types of neutral stimuli. They differ in their relative frequency of presentation and corollary in their familiarity but also in their emotional valence. These differences between self-referential stimuli and others thus concern low level as well as higher level properties of these stimuli. In order to build comprehensive theories of attention, it is therefore actually crucial to precisely identify factors driving attentional effects and to determine whether self-referential possible specific attentional properties are due to their “self” component or to other lower level components such as their familiarity.

To date, it is still difficult to conclude that self-referential stimuli are particularly prone to attract attention. Studies that have shown self-effects in attention often lacked really appropriate control in order to disentangle self-effects from lower level familiarity effects. Their results have been called into question and sometimes reinterpreted by other studies. Actually, most existing data does not seem in favour of a late selection theory of attention assuming that we processed semantically all incoming information before a selection occurs. Rather, as Harris et al. (2004) wrote, there is an “emerging consensus favouring a modified version of early selection theory” and it seems that “late selection theorists greatly overestimated the capacity for parallel perceptual analysis of complex stimuli" (p. 28). In Chapters 6 to 9 we will attempt to answer this question of self specificity in attention more precisely using the self-face.

5. Conclusion

This chapter aimed at examining whether self-referential stimuli are special. We overviewed three different topics in which self-referential stimuli have been assessed regarding their specificity. First, we have seen that previous research seems to indicate that self-referential stimuli do not benefit from qualitatively different representation by comparison with comparable other stimuli. So, even if we access self-referential stimuli in a particular way (i.e. on the one hand the access to our own physical appearance is quite restricted; on the other hand we have a privileged access to our psychological traits and knowledge) by comparison with non-self-referential stimuli, this does not seem to largely affect their representation in memory.

Secondly, we have reviewed literature on the neural correlates subtending representation of self-referential stimuli. Since the range of this literature is huge, we focused on neural correlates of one's own physical appearance. We have seen that specific cerebral regions seem preferentially implicated during processing of the self-face and other self-referential stimuli. Contrary to some drastic claims, complex cerebral network(s) distributed across both cerebral hemispheres probably play a role in the processing of such stimuli. Apparently, the right frontal cortex, the medial regions and the parietal cortices seem to have important implications within this or these networks. Nonetheless, we have also noted that a consensus has still to be found. Indeed, regions across virtually the whole brain have been activated somehow by self-referential processing, depending on the type of stimuli that were presented, of the task at hand, or of the way participants had to give their responses.

Finally, we reviewed part of the attention literature in which the own name has been extensively used in order to assess opposing theories of attention. Whereas earlier studies seemed in favour of a late selection theory of attention, in that they indicated that the own name was particularly prone to capture attention, later data rather seem to support early selection theories by showing that the own name does not automatically attract attention. Precise conditions determining the ability of self-referential to attract attention are yet to be defined.

In sum, this review calls into question the intuitive claim that self-referential stimuli must be special. We have seen that it is not necessarily true that they must elicit special responses or trigger special processing because they pertain to our most private, subjective and intimate aspects. We have seen that within these three different areas of research, methodological limitations often prevent the forming of firm conclusions about a specific status of self-referential stimuli. Often, self-referential stimuli have been compared to neutral and/or unfamiliar stimuli that differ not only according to their self aspect but also according to other factors such as their familiarity or emotional valence (for a review see Gillihan & Farah, 2005). Only recently researchers are taking more and more seriously this need for adequate control into account. We will of course do so in the present work and will try to contribute towards an answer to this still unresolved question.

Chapter 3

AN OUTLINE OF PRESENT STUDIES

Self-referential stimuli have been extensively studied. We have seen throughout previous chapters that their use can aim at two main purposes. On the one hand, processing of self-referential stimuli can be examined in order to understand the way an organism is (or is not) conscious of various aspects of its own Self (self-consciousness). Chapter 1 has illustrated how important it is to clearly define self-consciousness before beginning such an enterprise. Also, we have seen that as a consequence, self-referential stimuli must be carefully chosen in relation with the specific facet of self-consciousness one wants to investigate.

On the other hand, self-referential stimuli have been studied for themselves in order to examine whether they are special. The ultimate goal of this approach is to know whether the Self is special by comparison with non-self. Chapter 2 has shown that in this context, self-referential stimuli have been presented in various tasks to assess whether they elicit specific pattern of behaviour or brain activation by comparison with non-self-referential stimuli. There is some indication that self-referential stimuli might be processed by specific neural regions. However, systematic studies using adequate control of confound variable such as familiarity are only beginning to be conducted. Up to now, the answer to that question is still unknown and it would be premature to claim that the Self is indeed special.

Note that these two views are not mutually exclusive. Remind also that on some occasion self-referential stimuli have been used just as tool in various fields. In a third kind of approach, their salience and high-relevance for their owners have been used to enhance chances of eliciting responses by comparison with less salient stimuli. The present work definitively comes within the context of the second approach. It is aimed at assessing whether the self-face (and the self-body) is special by comparison with other faces (and bodies).

We chose the self-face among the range of possible self-referential stimuli for several reasons. First, it is probably the only self-referential stimulus that is unique and different for each individual (with the exception of identical twins). Indeed, even if the combination of all self-related information contributes to the formation of a unique entity (i.e., the Self), almost each individual self-related information can be shared with other people (the voice being an obvious exception). People share their last name at least with their family members and their first name with hundreds to millions of people (depending on their parents' will and imagination). People's own traits, knowledge, goals, occupations, beliefs and even memories can also be shared by their close relative as well as by complete strangers. The self-face therefore constitutes a unique and really distinctive self-referential stimulus. Second, faces in general have been described as a special class of stimuli. Therefore if the Self and all its components are really special, the self-face should be distinguished from other faces by the cognitive system even if it is a member of the face category and differential responses should be observed between the self-face and other faces. Finally, the self-face being part of one's own physical appearance (unlike traits or more abstract self-related information), it can be studied in various paradigms involving vision. This perceptual modality is certainly the one that has been the most intensively studied. This offers a huge range of possibilities based on acknowledged existing paradigms to engage in a systematic and controlled examination of self-referential stimuli.

For all these reasons, we thought that the self-face would be an ideal candidate to partially answer the question of whether self-referential stimuli are special. However, something is not special per se. It is by comparison with something else. We thus needed to compare responses to the self-face to other kind of responses. An obvious point of comparison was the use of other faces. However, it could not be any face because a lot of factors differentiate the self-face from an unfamiliar face. The self-face is very familiar since we regularly see it from birth. We have encoded it over a long period of time in which we have encountered it across various configurations. Even if we can not see it directly, we regularly perceive it in dynamic "real life" conditions (contrary to famous face that we only see through screens or pictures for instance). In order to estimate self-effects at best and to prevent other factors such as familiarity to create confound, we chose to compare responses to the self-face to responses to another personally and highly familiar face. In all the experiments presented below, we recruited pairs of gender-matched participants. They were friends or fellow students (i.e., involved in a positive relationship), had approximately the same age and encountered each other on a regular basis. This way, each of them served as control familiar face for the other one. Moreover, as each individual participant's face had both status of self-face and other familiar face, possible differences between the two kinds of faces could not be explained by particular and distinctive facial features one could have.

In this work, we have examined the specificity of the self-face (and of the self-body) in the same three main topics as presented in Chapter 2: representation in memory, neural correlates and attentional properties. The present account begins with Chapter 4 that describes a study examining the accuracy of the representation of the self-face in memory. Section 2 of Chapter 2 illustrated how the physical constraints pertaining to our own face affect the way it is represented in memory. However, previous studies mainly investigated the self-face representation in regards with its orientation (i.e., mirror versus normal view, canonical view) or efficiency (i.e., processing advantage in terms of reaction times) and little is known about its precision and accuracy. We filled this gap using a psychophysics method involving gradual facial transformations. These transformations were applied on the self-face or on the other familiar face and consisted in incrementally moving the eyes inwards or outwards by steps of two pixels (up to 18 pixels). The resulting pictures were presented in a random order and participants were asked to judge from memory whether each picture was intact or altered. In order to determine the extent to which the representation of the familiar faces is precise in memory, participants' performance was compared to that of other participants involved in a perceptual discrimination task.

In Section 3 of Chapter 2, we have seen that neural correlates underlying self-face representation and recognition are not clearly established yet. Moreover, we have also noted that the self-recognition from body shape and its neural correlates has been a little neglected in the literature to date. Chapter 5 describes an fMRI study aimed at investigating further these questions. The paired presentation of self-face and self-body also allowed examining the important question of common neural regions involved in the processing of self-referential stimuli independently of the stimulus domain. We used similar facial alterations than in the preceding study and designed an equivalent waist-hip ratio alteration for bodies.

Participants' brain responses were recorded while they were judging whether pictures of themselves and of a close friend were intact or altered.

In following chapters studies investigating the third main topic related with attentional properties of the self-face are presented. Section 4 of Chapter 2 showed that self-referential stimuli might not have an unconditional attention-grabbing capacity. Previous studies claiming that self-referential stimuli have particular attentional properties often lacked adequate controls allowing such a claim. Therefore, circumstances allowing important stimuli such as the self-face to be preferentially selected by attention are still unclear. Chapter 6 describes a set of three experiments aimed at determining whether the self-face has a specific and enduring distractive power by comparison with other familiar and unfamiliar faces when it is presented irrelevantly with the task at hand. Moreover, precise conditions in which the self-face produces distraction are examined in regards with its spatial location within or outside the participant's presumed focus of attention. By contrast with Chapter 6 only investigating whether the self-face has some distractive power, Chapter 7 presents three experiments examining more precisely whether the self-face is particularly able to *capture* attention and whether a face per se captures attention by comparison with other stimuli. In this study, we used an inattentional blindness paradigm in which the participant's own face or another familiar or unfamiliar face was unexpectedly presented while participants were engaged in an unrelated demanding task. Finally, Chapter 8 presents an eye-tracking experiment simultaneously studying the self-face's ability to capture and hold attention compared with other faces. Participants' eye-movements were recorded while they were engaged in a visual search task implying faces but in which the facial identity or familiarity was irrelevant. Moreover, the effect of the status of the self-face as target or distractor was also assessed.

In the ninth and last chapter, results of all above-mentioned studies will be discussed in relation with previous literature. We will try to give an update on the question of the self-face specificity in regards with our three main topics. We will also propose some perspectives for future work that should be done.

Chapter 4

THE ACCURACY OF MEMORY FOR PERSONALLY KNOWN INDIVIDUALS' FACES

Serge Brédart and Christel Devue (2006). *Perception, 35,* 101-106.

Abstract

The present study was aimed at evaluating whether the very high accuracy of memory for familiar faces demonstrated by Ge, Luo, Nishimura and Lee (2003) with a very familiar famous person may generalises to faces of personally known individuals. The accuracy of participants' perceptual memory for a close colleague's face and for their own face was evaluated by presenting original and manipulated pictures of these two target persons. The manipulation consisted of increasing or decreasing the interocular distance. As in Ge et al.'s study, results indicated that proportions of correct recognition of the original faces, and Just Noticeable Differences for the detection of alterations in the recognition task, were not significantly different from the corresponding measures in a perceptual discrimination task performed by a sample of participants who did not know the target persons at all. High accuracy of memory generalises to faces of personally known individuals.

Introduction

Recently, Ge, Luo, Nishimura and Lee (2003) have proposed an interesting experimental procedure to examine the accuracy of our memory for highly familiar faces. Instead of presenting faces of different individuals, they presented the original and manipulated pictures of one target face: Mao Tse-Toung's face that was particularly familiar to their Chinese participants. The original face was slightly altered on only a single dimension: the interocular distance was either increased or decreased. The participants' task was to judge whether each seen face was that of Mao or an altered version of Mao's face. By presenting one face stimulus at a time to the participants and asking them to judge whether the seen face is the same as, or different from, the image of Mao that they have in memory, the minimal change needed for a face stimulus to be judged as an altered picture of Mao was determined. This Just Noticeable Difference (JND) provided a threshold level estimation of the accuracy of participants' memory for Mao's face. Ge et al. showed that this memory threshold approximated the perceptual discrimination threshold of participants who were not familiar with Mao's face. Using the procedure proposed by Ge et al. it was possible to study the recognition of familiar faces in a more precise fashion. More than the ability to identify an individual among others, this procedure enables the investigation of the ability to detect changes in a familiar face from memory.

Ge et al. showed a remarkably accurate recognition of a famous individual's face who was mainly known from his standard portrait. The important question of whether such accuracy occurs for very familiar faces in general or only for those famous people who are mainly known from a particular iconic portrait (e.g. Mao, Che Guevara, etc.) cannot be answered from the Ge et al. study. From their study, it is unclear whether people have an excellent memory for Mao's face, or an excellent memory for the particularly famous portrait that was used as the stimulus. To address this point we examined the accuracy of memory for highly familiar faces of personally known individuals such as a close colleague's face and one's own face. We do not know personally familiar people from a particular standard portrait. Instead, we have experienced a variety of exemplars both of our own face and of close colleagues' faces. We have seen each of these faces in different views, showing different facial expressions, and possibly with different hairstyles, make up, and so on. However, several authors have stressed that the distribution of views seen from one's own face is more restricted than the distribution of views from other familiar faces (Laeng & Rouw, 2001; Troje & Kersten, 1999). Because this difference could be relevant to the formation of robust representations for faces (Tong & Nakayama, 1999), in the present study the recognition of one's own face was systematically compared with the recognition of a close colleague's face. JNDs in the self-recognition task were compared with JNDs in the colleague's face recognition task (within-subjects comparison). Like in the Ge et al. study, these JNDs were respectively compared with JNDs from another group of participants involved in a perceptual discrimination task (between-subjects comparison). However, the ease of detection of alterations is not the only aspect of accuracy. The ability to recognize the original, non-altered, version of the target face also seems important. Hence the proportion of correct responses to the original version of the target face was also used as a dependent measure.

Methods

Participants

Twenty-four volunteers (12 women) aged between 17 and 29 years participated. Twelve of them (6 women) participated in a recognition task. They had known their same gender colleague for between 2 and 5 years (mean 3.7 years). The other twelve participants were recruited as controls and took part in a perceptual discrimination task. Participants in the recognition task were totally unfamiliar to participants in the discrimination task. All participants had normal or corrected-to-normal vision.

Materials

The twelve experimental participants were photographed in front of the same beige wall and were depicted with a neutral facial expression. A full face, frontal view colour photograph of each experimental participant was taken at a distance of 150 cm with a digital camera (Nikon Coolpix 2500). None of these participants had facial hair or wore glasses. Each image has a width of 16 cm and height of 21 cm (450 by 587 pixels) with a resolution of 0.035 cm per pixel or 2.41 min of arc per pixel. The image manipulation software GIMP was used to increase or decrease the distance between each target face's eyes, two pixels at a time (one pixel for each eye). The resultant images were then retouched to create natural-looking shadings (see Figure 1). From each target face, 9 new versions with a wider interocular distance were created for the eye-out condition, and 9 new versions with a smaller interocular distance were created for the eye-in condition. Hereafter, these new versions will be referred to as "*Target + X*" or "*Target – X*", where X indicated the number of pixels (from 2 to 18) by which the distance between the eyes of the new version differed from that of the original target face. The original face will be referred to as "*Target*".

Procedure

Participants were tested individually. Stimuli were displayed on a 17-inch monitor at a viewing distance of 50 cm. The stimulus presentation and data recording were controlled by the E-prime software. Each participant in the recognition task saw 19 different pictures of her/his own face and 19 different pictures of their same gender colleague (the 9 versions of the eye-out condition, the 9 versions of the eye-in condition and the original face, for each target person). Each picture was presented a total of 20 times. Thus, during the experiment itself, the participants saw a total of 760 stimuli (i.e. 20 trials x 19 different pictures per target face x 2 target faces). Trials were grouped into two main blocks: trials on the own face / trials on the colleague's face. Half of the participants saw the 380 pictures of their own face first. The remaining participants saw the 380 pictures of their colleague's face first. Within each block, trials were presented in a random order. There was a 2 min break every 190 trials. Each picture was presented until the participant responded, or until a maximum of 10 s had elapsed. Participants were told that they were going to see pictures of their own face and pictures of a colleague (the name of the colleague was given), and that some of these pictures had been manipulated so that the interocular distance was either increased or decreased while some of them were intact (non-manipulated). Participants were instructed to judge whether each presented picture was intact ("Yes" response) or manipulated ("No" response).

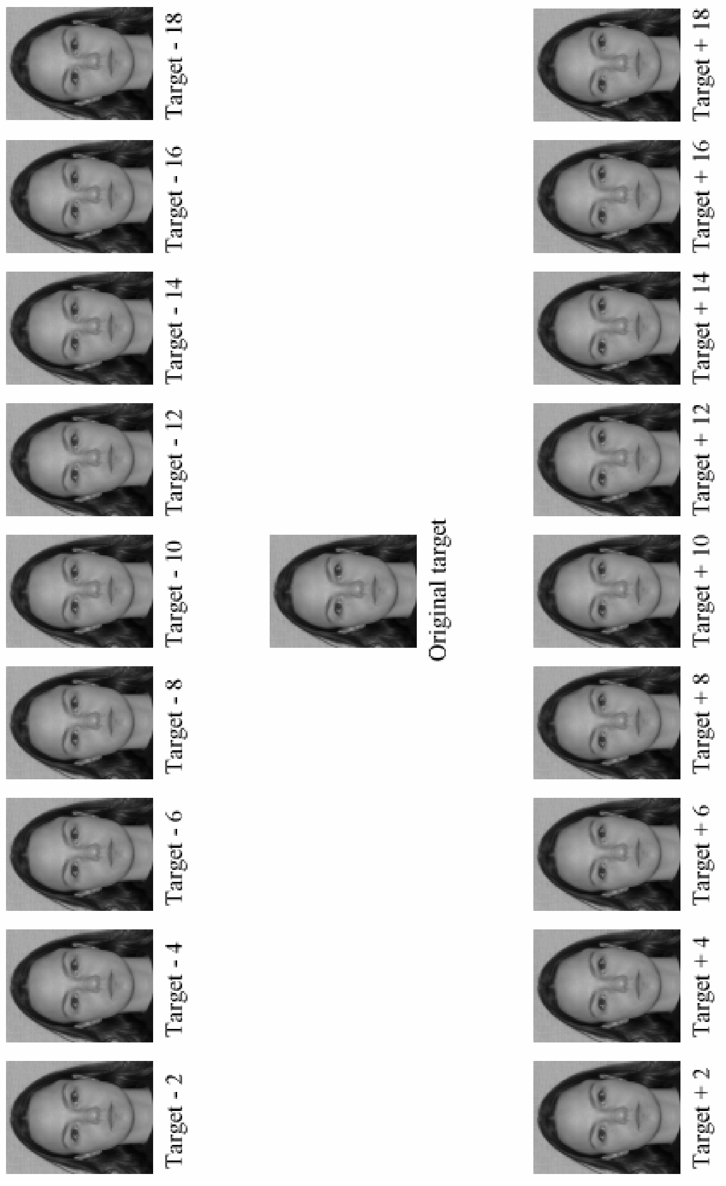

Figure 1. An example of stimuli used in the experiment. The original target was manipulated on one single dimension: the inter-ocular distance was either decreased (Target - X) or increased (Target + X).

Participants responded by pressing a response key on a computer keyboard. No feedback was given. The experiment took about 70 min. Before each of the two main blocks of items, the participants were shown the complete set of the 19 pictures that were to be presented in the block, once and in a random order. No response was required during this pre-experimental phase.

Since people are usually more familiar with the mirror-reversed view of their own face than with the normal view, and conversely, more familiar with the normal view of other people's face than with the mirror view, participants were shown their own face in a mirror orientation and their colleague's face in a normal orientation.

In the discrimination task, each participant was shown pairs of pictures of a same gender unfamiliar face (i.e., the face of an individual who participated in the recognition task). Each pair of pictures consisted of the target face's original picture and one manipulated picture of the same face (from *Target – 18* to *Target + 18*), or two copies of *Target*. Pictures had the same size as those presented in the recognition task. Participants were asked to judge whether the pairs of pictures were identical or different from each other in any way. As in the recognition task, they were told that the interocular distance had been manipulated on some pictures. Moreover, before starting the experimental trials, they were shown the 19 pictures to be seen later in the experiment. During the experiment itself, each participant saw a total of 380 pairs of pictures (i.e., 20 trials x 19 different pairs). The face of each participant in the recognition task was showed to one participant in the discrimination task.

Results

The rate of absence of response within the allowed 10 s was very low (0.12% in the recognition task and 0.57% in the perceptual discrimination task, i.e., less than 1% in both tasks). Figure 2 shows the mean proportions of trials in which participants judged that the presented face was altered in the recognition task. This figure also shows the mean proportion of trials in which participants judged that the two presented pictures of a face were different, in the discrimination task.

As in the Ge et al. study, each participant's threshold value in pixels was determined by interpolating the 75% correct response point. In the recognition task, the threshold value was calculated separately for each target face (own face or colleague's face).

In the recognition task, the proportions of correct responses to the original target pictures were similar for the person's own face (mean = 0.82; sd = 0.15) and for the colleague's face (mean = 0.85; sd = 0.15), *t*(11) < 1. In addition, a 2 (Target face: self *vs* colleague) X 2 (Condition: eye-in *vs* eye-out) ANOVA with repeated measures on both factors was carried out on the JNDs. This analysis revealed no main effect of the target face, no main effect of the condition, and no interaction effect (all *p*s > .10). In other words, the participants' performance was similar for their own face and for the colleague's face, on the one hand, and for increases and decreases in the interocular distance on the other hand. Descriptive data are presented in Table 1.

Condition	Eye-in		Eye-out	
Recognition task				
Own face	7.22 (2.78)	*17.40 (6.71)*	9.59 (4.08)	*23.10 (9.84)*
Colleague's face	7.23 (2.61)	*17.43 (6.29)*	8.65 (2.95)	*20.86 (7.12)*
Discrimination task	7.42 (3.40)	*17.89 (8.20)*	7.71 (3.76)	*18.58 (9.08)*

Table 1. Means (standard deviations) of just noticeable differences in pixels (JNDs in min of arc are presented in italics) in the eye-in and eye-out conditions, for the own face and the close colleague's face (recognition task) and unfamiliar faces (perceptual discrimination task).

A 2 (Target face) X 9 (Decreasing distance) ANOVA with repeated measures on both factors showed no main effect of the target face (*F* < 1) and no interaction effect (*F* < 1) but revealed a significant effect of decreasing distance (*F*(8,88) = 79.64; *p* < .001): as the deviation from the Target increased, participants' detection of alteration increased (see Figure 2). Similarly, a 2 (Target face) X 9 (Increasing distance) ANOVA showed no main effect of the target face (*F* < 1), no interaction effect (*F*(8,88) = 1.85; *p* > .05), but revealed a significant effect of increasing distance (*F*(8,88) = 63.46; *p* < .001): again, as the deviation from the Target increased, participants' detection of alteration increased.

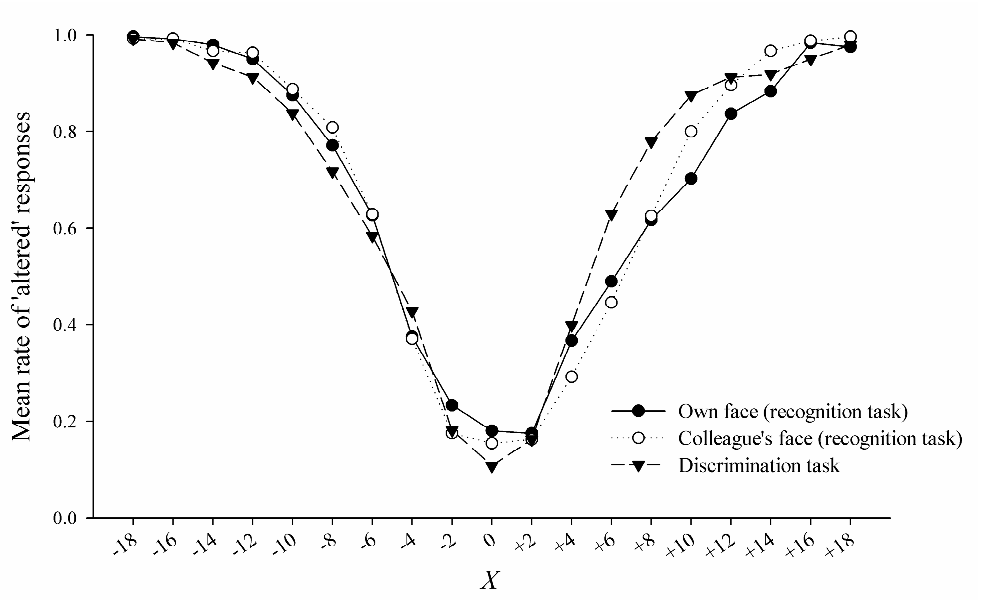

Figure 2. Mean rates of “altered” responses as a function of face alteration (from Target -18 to Target +18) for the own face and the close colleague’s face (recognition task), and unfamiliar faces (perceptual discrimination task).

Performance on the perceptual discrimination task was compared with performance on the recognition tasks. Independent *t*-tests showed that the proportion of correct “same” responses on the perceptual discrimination task (mean = 0.89; sd = 0.16) was not significantly different from the proportion of correct responses to the original version of the target faces in the recognition tasks ($t(22) = 1.12$; $p = 0.27$ for the own face; $t(22) < 1$ for the colleague’s face; see Figure 2). Similar comparisons were performed on the JNDs by conducting two mixed two-way 2 (Task) X 2 (Condition: eye-in *vs* eye-out) ANOVAs with repeated measures on the last factor. In the first analysis, JNDs from participants involved in the own-face recognition task were compared with JNDs from control participants, i.e., participants judging the same faces (unknown to them) in the perceptual discrimination task. This analysis revealed no effect of the task, no effect of the condition, and no interaction (all *p*s > .20). In the second analysis, JNDs from the participants’ responses to the colleague’s face in the recognition task were compared with JNDs from control participants’ responses in the perceptual discrimination task. This analysis revealed no effect of the task, no effect of the condition, and no interaction (all *p*s > .30).

Discussion

Our aim was to evaluate whether the highly accurate recognition of very familiar faces that Ge et al. (2003) found while using the standard portrait of a famous person (Mao) generalises to faces of personally known individuals. In the present study, Ge et al.'s procedure was used both with faces of the participants, and a close colleague of theirs. Results indicated that the mean proportion of correct recognition of the original face (whether it be one's own face or the colleague's face) in the recognition task was similar to the mean proportion of "same" responses in a perceptual discrimination task performed by control participants to whom the target faces were unknown. In addition, for both faces, JNDs in the recognition task were not significantly different from JNDs measured in the perceptual identification task. This pattern of results is identical to that reported by Ge et al. (2003). Moreover, the values of the JNDs are rather similar across Ge et al.'s first experiment and the present experiment: their values were around 20 minutes of arc while those reported here were a little bit smaller.

Results also showed that, in the recognition task, participants' performance was similar for the own face and the colleague's face whether the dependent measure was the proportion of correct identification of the original face or the JNDs. Therefore, the fact that the distribution of views from one's own face was restricted relative to other very familiar faces had no significant influence on the participants' performance. This is perhaps not so surprising since the task required participants to process pictures that presented faces in a full frontal view, i.e., a view that is easily available for one's own face as well as for other faces. On the other hand, no advantage for self-recognition was observed. This lack of advantage for the processing of self-face is consistent with previous work (e.g., Kircher et al., 2001, 2002). It seems that self-face recognition does not comply to the idea that people should be especially good at recognising stimuli that are relevant to themselves (Heatherton, Macrae, & Kelley, 2004).

It has been shown that the eyes are particularly important for the recognition of familiar faces (e.g. O'Donnell & Bruce, 2001). In future work, the Ge et al. (2003) procedure should be used to evaluate whether the high accuracy in detecting alterations holds even when other distances (e.g. the distance between the nose and the mouth) are manipulated.

In conclusion, the present results support the idea that high accuracy of memory for familiar faces is not limited to the recognition of famous individuals, or to their iconic portraits. It generalises to personally known individuals for whom we have a varied visual experience in that we encounter such faces under a variety of stimulus conditions and contexts.

Acknowledgements

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Chapter 5

HERE I AM: THE CORTICAL CORRELATES OF VISUAL SELF-RECOGNITION

Christel Devue, Fabienne Collette, Evelyne Balteau, Christian Degueldre, André Luxen, Pierre Maquet, and Serge Brédart (2007). *Brain Research, 1143,* 169-182.

Abstract

Recently, interest in the neural correlates of self-recognition has grown. Most studies concentrate on self-face recognition. However, there is a lack of convergence as to precise neuroanatomical locations underlying self-face recognition. In addition, recognition of familiar persons from bodies has been relatively neglected. In the present study, cerebral activity while participants performed a task in which they had to indicate the real appearance of themselves and of a gender-matched close colleague among intact and altered pictures of faces and bodies was measured. The right frontal cortex and the insula were found to be the main regions specifically implicated in visual self-recognition compared with visual processing of other highly familiar persons. Moreover, the right anterior insula along with the right anterior cingulate, seemed to play a role in the integration of information about oneself independently of the stimulus domain. The processing of self-related pictures was also compared to scrambled versions of these pictures. Results showed that different areas of the occipito-temporal cortex were more or less recruited depending on whether a face or a body was perceived, as it has already been reported by several recent studies. The implication of present findings for a general framework of person identification is discussed.

Introduction

The face is a physical characteristic that is critical to the identification of people we meet. The recognition of one's own face is also important. The ability to recognise one's own face appears to participate in maintaining a sense of self (Platek, Thomson, & Gallup, 2004). To recognise oneself, one must have the ability to build and retrieve a representation of one's physical appearance, and to regard the self as a different entity from others. Hence, many researchers view self-recognition as an indicator of self-awareness (see Gallup, Anderson, & Platek, 2003). Recently, the question of whether there are neural mechanisms which are distinctively related to the process of self-recognition (as compared with the recognition of other familiar people) has drawn the attention of a growing number of cognitive neuroscientists (for recent reviews see Gillihan & Farah, 2005; Keenan, Wheeler & Ewers, 2003; Keenan, Gallup, et al., 2003).

The examination of split-brain patients has demonstrated that both hemispheres are capable of self-recognition (Sperry, Zaidel, & Zaidel, 1979; Uddin, Rayman, & Zaidel, 2005). However, evidence that self-recognition preferentially involves the right hemisphere has been reported. Several studies have indicated a left-hand advantage in self-face recognition tasks in healthy participants (Keenan et al., 1999; Keenan, Freund, Hamilton, Ganis, & Pascual-Leone, 2000; Keenan, Ganis, Freund, & Pascual-Leone, 2000; Platek & Gallup, 2002; Platek, Thomson, et al., 2004; Zhu, Qi, & Zhang, 2004). Because of contralateral motor control, this left-hand advantage supports the view that the right hemisphere is predominant in self-recognition. A right hemispheric advantage for self-face recognition in a callosotomy patient has also been reported (Keenan, Wheeler, Platek, Lardi, & Lassonde, 2003; but see Turk et al., 2002, for a left hemisphere advantage in another split-brain patient). In addition, patients who were undergoing Wada tests were shown images of themselves morphed with a famous face during right and left hemispheric anaesthetization. After the anaesthesia has subsided, patients were asked about the face they were shown. They were more likely to report having seen themselves after the anaesthetization of the left hemisphere than after the anaesthetization of the right hemisphere (Keenan, Nelson, O'Connor, & Pascual-Leone, 2001). Finally, healthy participants showed greater right hemispheric activity, as measured by evoked potentials induced by transcranial magnetic stimulation, while presented with morphed or masked pictures of their own face as opposed to pictures of another person (Keenan et al., 2001; Théoret et al., 2004).

However, there are studies that support the opposite view that the left hemisphere has a dominant role in self-recognition. In one study, already mentioned here above, a split-brain patient was presented with morphed images blending his own face with a familiar person's face (Turk et al., 2002). These images were presented separately to the left and to the right hemispheres. In one condition the patient's task was to determine whether a presented image was himself while in another condition his task was to determine whether the image was the familiar person. The rate of self-detection was higher when the images were presented to the left than to the right hemisphere. On the opposite, detection of the familiar person was better when the images were presented to the right than to the left hemisphere. More recently, healthy participants were asked to choose which of two chimeric faces (one made from the left half and one made from the right half of their face) looked more like themselves (Brady, Campbell,& Flaherty, 2004). They showed a bias for the composite made from the half face that lies in their right visual field when they look at themselves in the mirror. When asked to make the same choice for similar images of a friend, they showed the opposite bias, i.e. they preferentially chose the composite made from the half face that lies in their left visual field when they look at their friend. Such results suggest that the left hemisphere is dominant for self-recognition and the right hemisphere is dominant for the recognition of others.

Results from functional neuroimaging studies of self-recognition using functional magnetic resonance imaging (fMRI) and PET are also controversial. Some studies concluded that the right prefrontal regions are critical for self-face recognition (Platek, Keenan, Gallup, & Mohammed, 2004; Keenan, Wheeler, & Ewers, 2003). More recently, Uddin, Kaplan, Molnar-Szakacs, Zaidel and Iacoboni (2005) reported that a neural network in the right hemisphere including the inferior frontal gyrus and the inferior parietal lobule is activated by the recognition of the self-face. In another experiment, Uddin et al. (2006) also confirmed the implication of the right inferior parietal lobule during self-face recognition and demonstrated for the first time the existence of a causal relationship between this region and self-recognition. To do so, they used a low-frequency repetitive transcranial magnetic stimulation to induce a virtual lesion in this region. This manipulation decreased the sensitivity of participants to detect their own face among morphed images of themselves and another highly familiar person while this manipulation had no effect when it was applied on the same region on the left side. However, there is also evidence suggesting bilateral involvement in self-face recognition. Kircher et al. (2000, 2001) reported activation in the right limbic system, left prefrontal cortex and temporal cortex during self-face processing. In a PET study Sugiura et al. (2000) found an implication of a large bilateral network involving the bilateral prefrontal cortex, the fusiform gyrus, the insula and the putamen on the left side, the supramarginal gyrus, the anterior cingulate, the presupplementary motor area and the hypothalamus on the right side during self-face recognition. More recently, Sugiura et al. (2005) conducted an fMRI study aimed at identifying the cortical mechanisms of self-face recognition by controlling the selectivity of the activation for the self-face. To do so, they compared the activity elicited for the self-face to that found with faces of different degrees of familiarity (i.e., a friend, an experimenter and a prelearned unfamiliar face) and excluded activation that could be explained by these differences of familiarity. They observed selective activation of the right occipito-temporo-parietal junction and frontal operculum, as well as in the left fusiform gyrus during self-face recognition. Platek et al. (2006) contrasted cerebral responses to self-face and another personally familiar face and also found an implication of both hemispheres (superior frontal gyrus, medial frontal and inferior parietal lobes on the right, and middle temporal gyrus on the left) during self-face identification.

Our first aim was to examine the cortical mechanisms of visual self-face recognition. The lack of convergence as to precise anatomical locations underlying self-face recognition motivated the present study. Moreover, previous studies considerably differed between each others with regard to the familiarity of the control face compared with the self-face. Depending on the studies and on the contrasts formally used in these studies, the control face was unfamiliar (Sugiura et al., 2000), recently learned (Sugiura et al., 2005), famous (Platek, Keenan, et al., 2004), or personally known to the participant (Kircher et al., 2000, 2001; Platek et al., 2006; Sugiura et al., 2005; Uddin, Kaplan, et al., 2005). Since control of familiarity is more efficient when the self-face is compared with a highly familiar face, we used a personally known, gender-matched, person as the control face in the current study.

Because distinguishing two highly familiar persons from each other is presumably very easy, we designed a task in which participants would have to identify their real facial appearance and that of their colleague among intact and altered pictures presented during a first event-related scanning session. In addition, the use of altered pictures allowed to increase stimulus variability and helped to decrease repetition suppression of the BOLD signal (Grill-Spector et al., 2006*)*. However, we were mainly interested in the processing of intact stimuli because responses to altered views of these faces might not reflect usual processing of such familiar stimuli (Platek et al., 2004). In other words, participants' task consisted in an "intact – altered" judgment both on pictures of themselves or of a close colleague, all these pictures being presented at random. The facial alterations consisted in moving the eyes inwards or outwards. To increase the statistical power of our analysis, we used a priori regions of interest found to be elicited in studies using similar contrasts (i.e., self-face *minus* other familiar face). These regions were the right inferior frontal gyrus (Platek, Keenan, et al., 2004; Uddin, Kaplan, et al., 2005), the left inferior frontal gyrus (Kircher et al., 2000), the right superior frontal gyrus (Platek et al., 2006), the right middle frontal gyrus (Platek et al., 2006), the right medial frontal gyrus (Platek et al., 2006), the left middle temporal gyrus (Platek et al., 2006), the left fusiform gyrus (Kircher et al., 2001), and the right inferior parietal lobule (Platek et al., 2006; Uddin, Kaplan, et al., 2005).

In addition, Gillihan and Farah (2005) recently noticed that there is a lack of studies of self-recognition from the body shape or body parts. Hence, the second aim of the current study was to investigate the cortical correlates of visual self-body recognition by assessing whether specific cortical regions underlie the own body recognition compared with the recognition of another familiar person's body. In a second event-related scanning session we asked participants to identify their real body-shape appearance and that of their colleague among intact and altered pictures. The body alterations consisted in increasing or decreasing the waist-to-hip ratio by changing the width of the hips. Again, the alterations were introduced to increase the difficulty of the task and to induce some variability in the stimuli. Due to the explorative nature of this comparison and to the lack of studies investigating this specific topic, we tentatively reported regions activated when comparisons between the processing of the self-body and the processing of another highly familiar person's body were examined.

Importantly, the use of body shapes as stimuli was also motivated by the third aim of determining which cerebral regions are selectively activated by self-processing regardless of the domain of presented stimulus (body or face). In some previous studies, the neural correlates of self-processing was explored using auditory presentations of the own name (e.g. Holeckova, et al., 2006; Perrin et al., 1999, 2005). However, contrary to the self-face or body, the own name is not an exclusively self-referential stimulus since it can be shared with other people. The self-voice is another type of auditory self-referential stimulus. It has the advantage of not being shared with other people. However, the use of such a stimulus may also be problematic. Indeed, hearing our own voice played back does not account for bone conductance and therefore a recording of our voice rarely sounds like our own voice heard from inside. Moreover, manipulating voices and faces is hardly comparable[5]. Hence, in addition to the self-face, the self-body was used instead of the own name or voice. Thus, for that purpose, data related to the self-face and data related to the self-body were collapsed and compared with the data related to the processing of the colleague's face and body. To increase the statistical power of our analysis on this contrast, we used a priori regions of interest found to be activated in studies investigating different tasks associated with auto-referential processing such as judgment of adjectives/sentences as self-descriptive or judgment of actions as self generated. These regions were the right/medial prefrontal cortex (Fossati et al., 2003; Kelley et al., 2002), the right anterior cingulate gyrus (Craik et al., 1999), the anterior insula (Farrer & Frith, 2002), the bilateral precuneus (Kircher et al., 2000, 2002; Ruby & Decety, 2001), the left inferior frontal gyrus (Craik et al., 1999; Kircher et al. 2002), and the left superior frontal gyrus (Ruby & Decety, 2001; Seger, Stone, & Keenan, 2004).

To summarize, in order to answer our three main questions, we used an event-related paradigm in which we examined cerebral activity elicited by the presentation of pictures depicting the face and the body of the participant and those of a close colleague. The participants' task was to discriminate between intact and altered pictures of themselves and of another highly familiar person. The alterations were used to prevent a fast habituation by

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[5] We thank an anonymous reviewer for this suggestion.

inducing some variability among the stimuli and also to increase the difficulty of the task, the main interest being the participant's ability to correctly identify intact bodies or faces. The intact self *minus* intact colleague contrasts presented below thus reflected the BOLD signal changes found when participants processed *their real physical appearance* compared to that of another personally familiar individual.

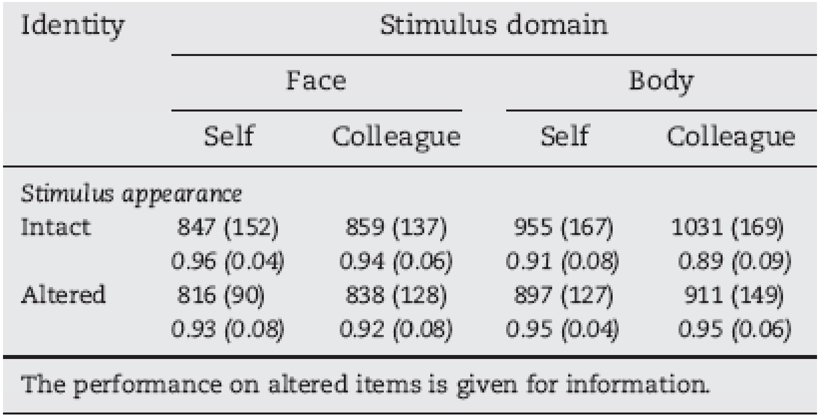
Finally, as it has been suggested by several recent previous studies (Downing, Chan, Peelen, Dodds & Kanwisher, 2006; Downing, Jiang, Shuman & Kanwisher, 2001; Peelen & Downing, 2005; Schwarzlose, Baker & Kanwisher, 2005; see also Gliga & Dehaene-Lambertz, 2005 for an ERP study) that faces and bodies are associated with distinct neural correlates we included two event-related control sessions in which participants passively viewed intact and scrambled pictures of their face (within one of these control sessions) or of their body (within the other control session). These two sessions would allow to determine the cerebral areas associated respectively with general face and body shape processing and would also allow to compare the neural substrates associated with the processing of these two kinds of stimuli. We used a priori regions of interest found to be elicited in studies comparing object or face processing to other kinds of stimuli (i.e., tools, letters or textures, scrambled pictures) processing. Regarding face recognition, these regions were the bilateral fusiform gyrus (Peelen & Downing, 2005, Puce, Allison, Asgari, Gore, & McCarthy, 1996), the right ventral occipital cortex (Peelen & Downing, 2005), the right occipitotemporal/inferior occipital sulci (Puce et al., 1996), and the bilateral lateral neocortex (Puce et al., 1996). Regarding body recognition, these regions were the right fusiform gyrus (Peelen & Downing, 2005) and the bilateral inferior temporal sulcus (Peelen & Downing, 2005).

Results

Behavioral data

The data from one participant whose response accuracy was more than 2.5 SD under the mean of the sample were discarded.

Accuracy. A 2 (Stimulus domain: face/body) X 2 (Identity: self/colleague) X 2 (Stimulus appearance: intact/altered) repeated measures ANOVA was carried out on proportions of correct responses and did not reveal any significant main effect, all *F*s < 2, *p* > 0.05. In addition, no interaction was significant except the Stimulus domain X Stimulus appearance interaction, *F*(1,18) = 13.16, *p* < 0.01. HSD Tukey post-hoc comparisons indicated that intact faces were better recognized than intact bodies (*p* < 0.05) and that altered bodies were better recognized than intact bodies (*p* < 0.05). No other difference reached significance. Descriptive data are presented in Table 1.



Identity	Stimulus domain			
	Face		Body	
	Self	Colleague	Self	Colleague
Stimulus appearance				
Intact	847 (152)	859 (137)	955 (167)	1031 (169)
	0.96 (0.04)	*0.94 (0.06)*	*0.91 (0.08)*	*0.89 (0.09)*
Altered	816 (90)	838 (128)	897 (127)	911 (149)
	0.93 (0.08)	*0.92 (0.08)*	*0.95 (0.04)*	*0.95 (0.06)*

The performance on altered items is given for information.

Table 1. Mean median reaction times in milliseconds and mean proportion of correct responses (in italics) as a function of the Identity and of the Stimulus domain (standard deviations are between parentheses).

Reaction times. Reaction times below 300 ms were excluded from the analyses. A 2 (Stimulus domain: face/body) X 2 (Identity: self/colleague) X 2 (Stimulus appearance: intact/altered) repeated measures ANOVA was performed on median correct reaction times and showed a main effect of Stimulus domain, *F*(1,18) = 14.37, *p* < 0.01, participants being faster for faces (*M* = 840, *SD* = 240) than for bodies (*M* = 949, *SD* = 279), and a main effect of Identity, *F*(1,18) = 9.84, *p* < 0.01, participants being faster for themselves (*M* = 879, *SD* = 230) than for their colleague (*M* = 910, *SD* = 234). There was also a main effect of Stimulus appearance, *F*(1,18) = 10.53, *p* < 0.01, intact stimuli (*M* = 923, *SD* = 267) being recognized more slowly than altered ones (*M* = 866, *SD* = 211). No interaction was significant (all *p*s >

0.05) except the Stimulus domain X Stimulus appearance interaction, *F*(1,18) = 14.67, $p < 0.01$.

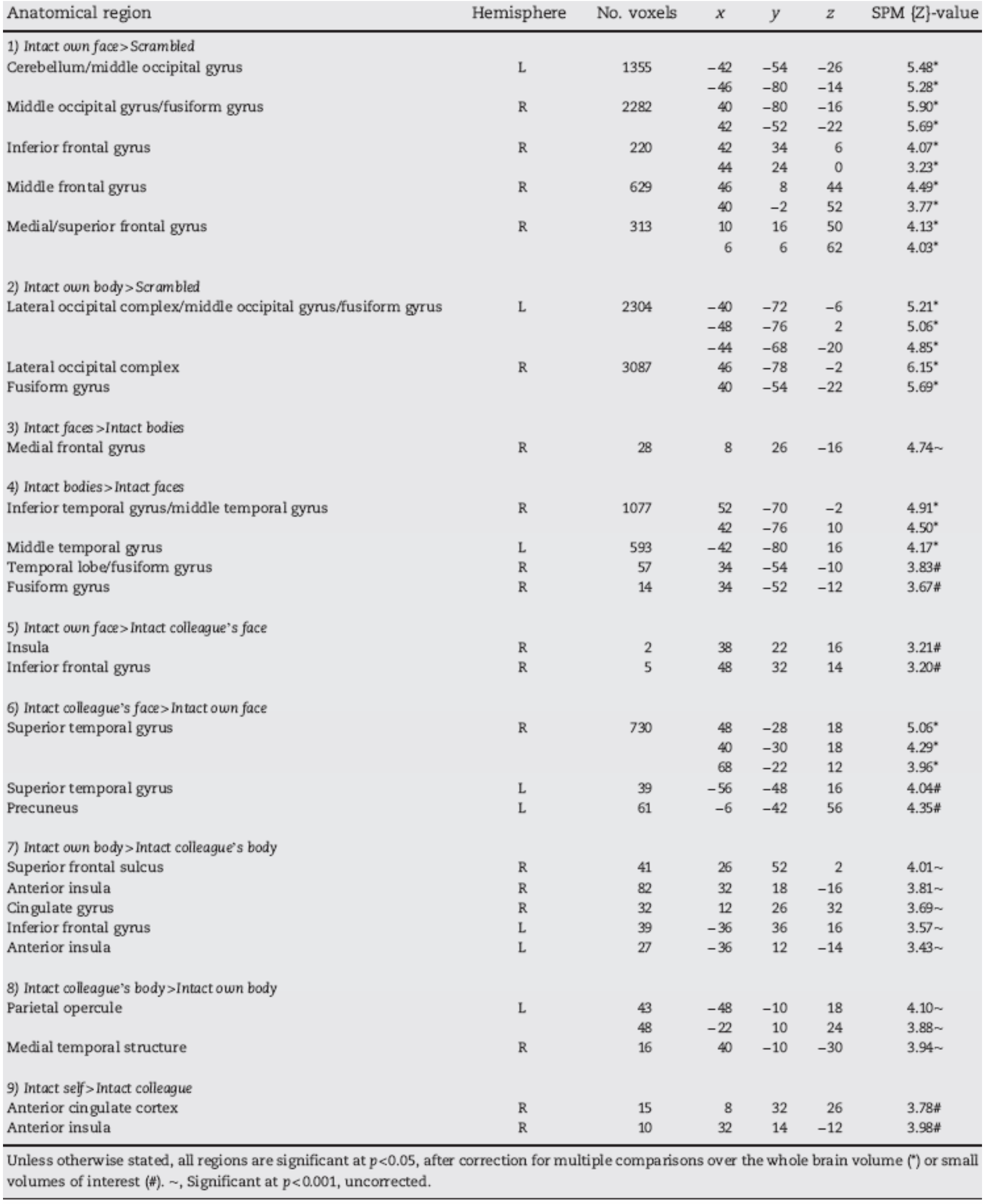
Tukey post-hoc comparisons indicated that intact faces were identified faster than intact bodies ($p < 0.001$), altered faces were identified faster than altered bodies ($p < 0.001$), altered bodies were identified faster than intact bodies ($p < 0.001$) and finally intact faces were identified faster than altered bodies ($p < 0.01$). No other comparison reached significance (see Table 1 for descriptive data).

These results showed that processing faces was faster than processing bodies, and that processing self-relevant stimuli was faster than processing stimuli depicting a colleague. However, Identity and Stimulus domain did not significantly impact the proportions of accurate responses. The effect of Stimulus appearance was not of first importance here since we were interested in the analysis of BOLD signals elicited by intact pictures.

Imaging data

First, intact faces and bodies were compared with, respectively, scrambled faces and bodies in order to check whether the same cerebral areas associated respectively with face and body processing as those reported earlier (Downing et al., 2001, 2005; Peelen & Downing, 2005; Schwarzlose et al., 2005) were activated. Faces and bodies elicited responses in close but segregated regions of the occipital cortex (Figure 1). Perception of faces was associated with a bilateral cerebral activity in the middle occipital gyrus, extending to the fusiform gyrus on the right and to the cerebellum on the left, as well as with activation of a large frontal area on the right side (middle and inferior frontal gyrus, and medial/superior frontal gyrus) (see Table 2).

Perception of bodies was associated with activity in the fusiform and lateral occipital complex bilaterally, and with activity in the left middle occipital gyrus (see Table 2). These findings are consistent with previous literature (Downing et al., 2001, 2005; Peelen & Downing, 2005; Schwarzlose et al., 2005). Direct comparisons between faces and bodies are reported in Table 2 (contrasts (3) and (4)).



Anatomical region	Hemisphere	No. voxels	*x*	*y*	*z*	SPM {Z}-value
1) Intact own face > Scrambled						
Cerebellum/middle occipital gyrus	L	1355	−42	−54	−26	5.48*
			−46	−80	−14	5.28*
Middle occipital gyrus/fusiform gyrus	R	2282	40	−80	−16	5.90*
			42	−52	−22	5.69*
Inferior frontal gyrus	R	220	42	34	6	4.07*
			44	24	0	3.23*
Middle frontal gyrus	R	629	46	8	44	4.49*
			40	−2	52	3.77*
Medial/superior frontal gyrus	R	313	10	16	50	4.13*
			6	6	62	4.03*
2) Intact own body > Scrambled						
Lateral occipital complex/middle occipital gyrus/fusiform gyrus	L	2304	−40	−72	−6	5.21*
			−48	−76	2	5.06*
			−44	−68	−20	4.85*
Lateral occipital complex	R	3087	46	−78	−2	6.15*
Fusiform gyrus			40	−54	−22	5.69*
3) Intact faces > Intact bodies						
Medial frontal gyrus	R	28	8	26	−16	4.74~
4) Intact bodies > Intact faces						
Inferior temporal gyrus/middle temporal gyrus	R	1077	52	−70	−2	4.91*
			42	−76	10	4.50*
Middle temporal gyrus	L	593	−42	−80	16	4.17*
Temporal lobe/fusiform gyrus	R	57	34	−54	−10	3.83#
Fusiform gyrus	R	14	34	−52	−12	3.67#
5) Intact own face > Intact colleague's face						
Insula	R	2	38	22	16	3.21#
Inferior frontal gyrus	R	5	48	32	14	3.20#
6) Intact colleague's face > Intact own face						
Superior temporal gyrus	R	730	48	−28	18	5.06*
			40	−30	18	4.29*
			68	−22	12	3.96*
Superior temporal gyrus	L	39	−56	−48	16	4.04#
Precuneus	L	61	−6	−42	56	4.35#
7) Intact own body > Intact colleague's body						
Superior frontal sulcus	R	41	26	52	2	4.01~
Anterior insula	R	82	32	18	−16	3.81~
Cingulate gyrus	R	32	12	26	32	3.69~
Inferior frontal gyrus	L	39	−36	36	16	3.57~
Anterior insula	L	27	−36	12	−14	3.43~
8) Intact colleague's body > Intact own body						
Parietal opercule	L	43	−48	−10	18	4.10~
		48	−22	10	24	3.88~
Medial temporal structure	R	16	40	−10	−30	3.94~
9) Intact self > Intact colleague						
Anterior cingulate cortex	R	15	8	32	26	3.78#
Anterior insula	R	10	32	14	−12	3.98#

Unless otherwise stated, all regions are significant at $p<0.05$, after correction for multiple comparisons over the whole brain volume (*) or small volumes of interest (#). ~, Significant at $p<0.001$, uncorrected.

Table 2. Significant BOLD signal changes in relevant contrasts.

After having identified the regions implicated in the processing of faces and bodies, we examined the contrasts of central interest in this study, i.e. the contrasts that assessed which cortical areas are specifically implicated in the processing of self related pictures and in the processing of pictures depicting another highly familiar person.

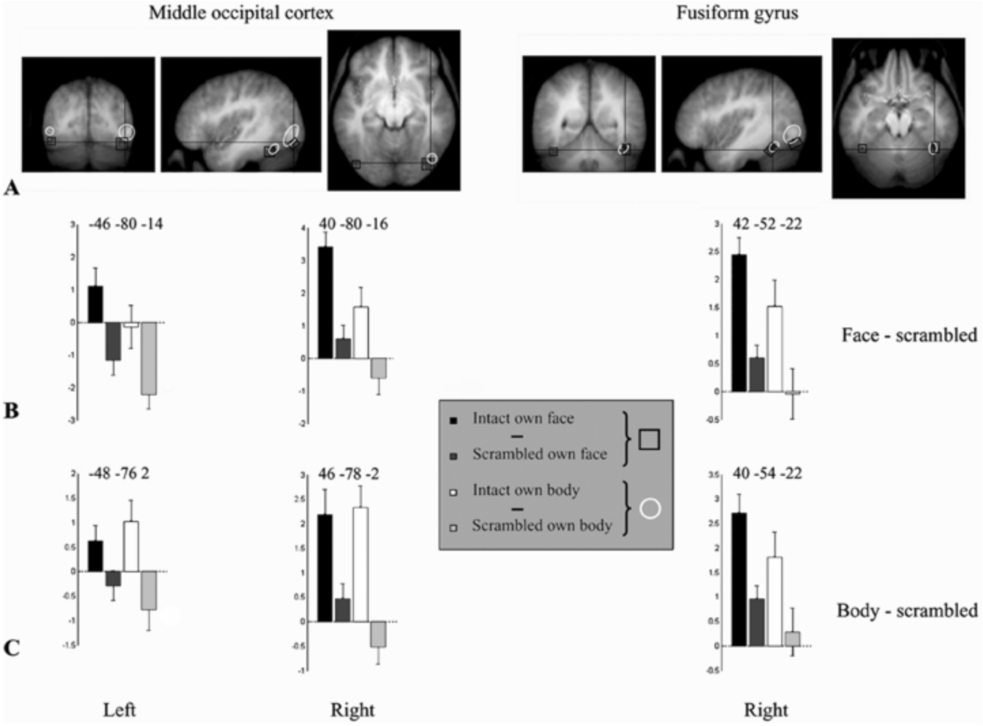


Figure 1. Illustration of brain activity observed when intact pictures (faces and bodies) were compared to scrambled pictures. Regions that showed activity associated with the processing of faces are boxed in black; Regions that showed activity associated with the processing of bodies are circled in white. (A) Regions with significant rCBF increase (corrected p value < .05) are superimposed upon a T1-weighted magnetic resonance imaging slice normalized into the MNI space. Coordinates of all significant regions are given in Table 2. Coronal sections are shown respectively 80 and 55 mm posterior to the anterior commissure. (B) Mean parameter estimates (arbitrary units) in the regions detected in the contrast Face - Scrambled are displayed for, from left to right, Intact own face, Scrambled own face, Intact own body and Scrambled own body. (C) Mean parameter estimates (arbitrary units) in the regions detected in the contrast Body – Scrambled are displayed for, from left to right, Intact own face, Scrambled own face, Intact own body and Scrambled own body. Error bars represent SEM.

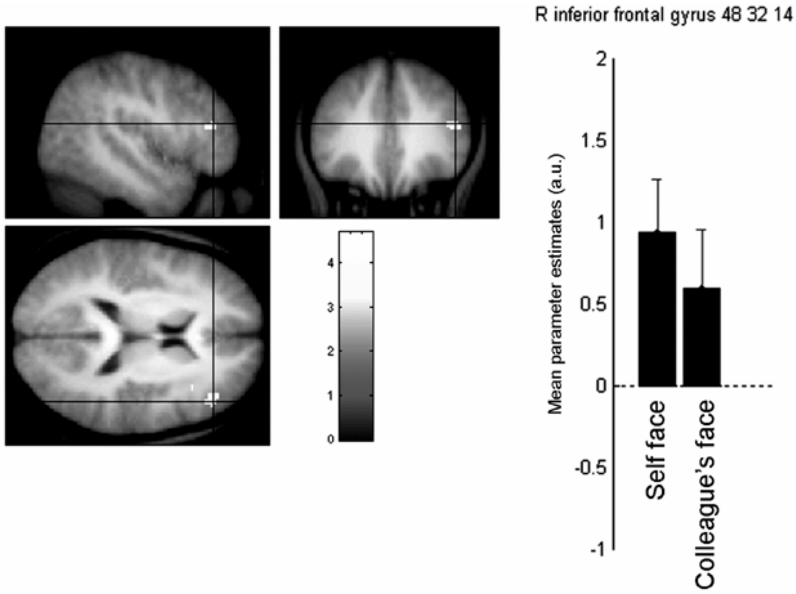


Figure 2. Illustration of brain activation elicited in the right inferior frontal gyrus by the recognition of the intact own face in comparison with the recognition of another highly familiar face. Coordinates of all significant regions are given in Table 2. *Left.* Region with significant rCBF increase (corrected at p<0.05 after applying small volume corrections) is superimposed upon a T1-weighted magnetic resonance imaging slice normalized into MNI. Coronal section is shown 32 mm anterior to the anterior commissure. *Right*. Mean parameter estimates (arbitrary units) in the right inferior frontal gyrus for Intact own face and Intact colleague's face. Error bars represent SEM.

Intact own face > *Intact colleague's face.* A significant response was identified in the right inferior frontal gyrus (Figure 2), consistent with literature (Keenan, Wheeler, Gallup, & Pascual-Leone, 2000; Kircher et al., 2000, 2001; Platek, Keenan, et al., 2004; Platek et al., 2006; Sugiura et al., 2000; Uddin, Kaplan, et al., 2005), as well as in the right insula. Contrary to previous studies (Kircher et al., 2000, 2001; Sugiura et al., 2000, 2005), no significant implication of the left fusiform was found.

Intact colleague's face > *Intact own face.* The processing of the colleague's face elicited activity in the right superior temporal gyrus. With a priori locations of interest defined from studies that reported a contrast as close as possible as the present one (other highly familiar face *minus* own face, Platek et al., 2006; Uddin, Kaplan, et al., 2005), a significant differential response was observed in the left precuneus and in the left superior temporal gyrus. However, parameter estimates showed that these areas were actually differently deactivated for the colleague's face and for the self-face (see Figure 3 for an example).

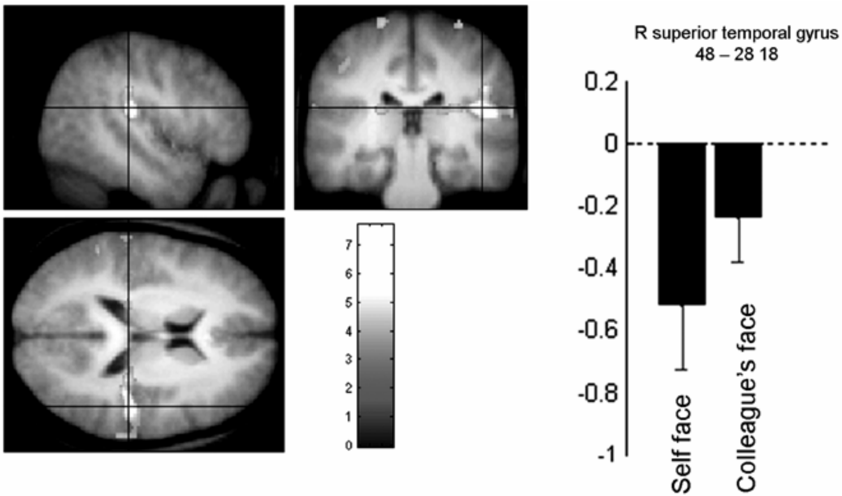


Figure 3. Illustration of brain deactivation in the right superior temporal gyrus observed with the comparison of a familiar face to the own face. Coordinates of the region is given in Table 2. *Left.* Region with significant rCBF decrease (corrected at $p<0.05$) are superimposed upon a T1-weighted magnetic resonance imaging slice normalized into MNI. Coronal section is shown 28 mm posterior to the anterior commissure. *Right.* Mean parameter estimates (arbitrary units) in the right superior temporal gyrus for Intact own face and Intact colleague's face. Error bars represent SEM.

Intact own body > Intact colleague's body. Significant responses were detected at a threshold of $P_{uncorrected} = 0.001$ in the right superior frontal sulcus, right cingulate cortex, left inferior frontal gyrus, as well as in the anterior insula bilaterally. None of these results survived correction for multiple comparisons.

Intact colleague's body > Intact own body. Significant responses were detected at a threshold of $P_{uncorrected} = 0.001$ in the left parietal opercule and in a right medial temporal structure close of the lateral part of the hippocampus. None of these results survived correction for multiple comparisons.

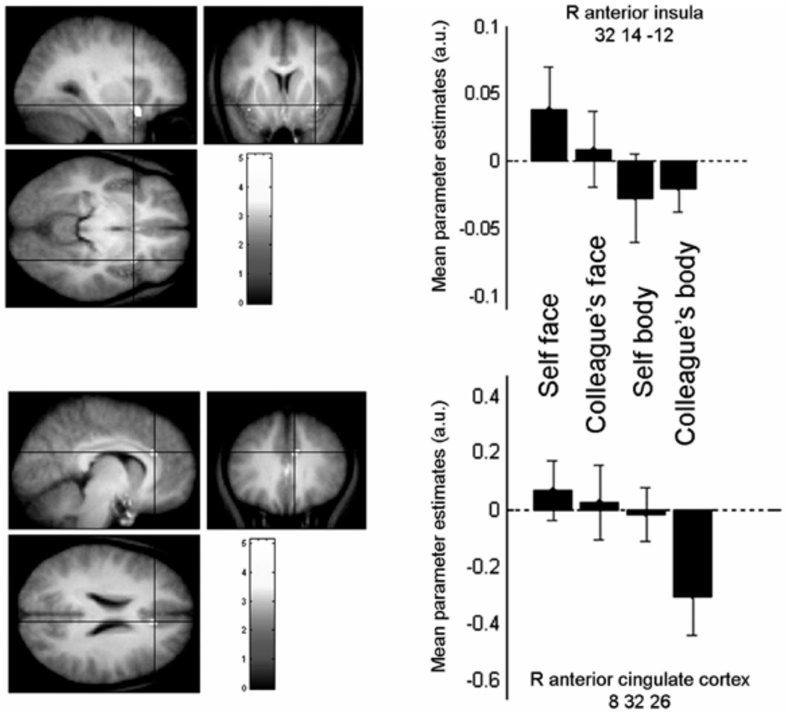


Figure 4. Illustration of brain (de)activation in the right anterior insula (top) and right anterior cingulate (bottom) observed for the processing of oneself by comparison to the processing of another person regardless of the Stimulus domain. Coordinates of the regions are given in Table 2. *Left.* Regions with significant rCBF increase/decrease (corrected at $p<0.05$ after applying small volume corrections) are superimposed upon a T1-weighted magnetic resonance imaging slice normalized into MNI. Coronal section is shown 32 mm anterior to the anterior commissure. *Right*. Mean parameter estimates (arbitrary units) in the right anterior insula and in the right anterior cingulate for, from left to right, Intact own face, Intact colleague's face, Intact own body and Intact colleague's body. Error bars represent SEM.

Finally, we examined whether specific regions were implicated in the processing of self-related pictures independently of the Stimulus domain.

Intact self > *Intact colleague.* This analysis was based on a priori locations from previous literature related to self-processing. Interestingly, when activation associated with seeing intact stimuli depicting the colleague (faces and bodies) was substracted from activation due to seeing stimuli depicting the participant herself, a significant response was found in the right anterior insula, consistent with literature (Farrer & Frith, 2002; Fink et al., 1996; Kircher et al., 2000, 2001). The response in the right dorsal anterior cingulate also tended to be significant ($Z = 3.78$, $p = 0.058$), consistent with previous findings (Craik et al., 1999; for a review, see Northoff & Bermpohl, 2004) (see Figure 4).

Discussion

The present study had three main objectives. First, it was aimed at clarifying the specific neural correlates associated with the recognition of the self-face compared with the recognition of another highly familiar and personally known person. Second, we wanted to test whether specific neural substrates are implicated in the recognition of the self-body in comparison with the recognition of another highly familiar body. Finally, it was tested whether there are specific regions implicated in self-processing independently of the stimulus domain. In order to answer these three questions, we measured BOLD responses elicited while the participants' task was to discriminate between intact and altered pictures of themselves and of a close colleague. An additional objective of that study was to verify, from our two control sessions, whether the areas of the cortex activated by faces and bodies were similar to those that have been recently reported (Downing et al., 2001, 2005; Peelen & Downing, 2005; Schwarzlose et al., 2005).

As far as the first objective was concerned, our data indicated that the processing of the own-face involved specific activation of the right inferior frontal gyrus and of the right insula in comparison with the processing of another highly familiar person's face. This implication of the right inferior frontal gyrus is consistent with previous studies reporting that this region is involved in the distinction between self and others (Uddin, Kaplan, et al., 2005) or in the attentive processing of the own-face (Sugiura et al., 2000). The implication of the right (Kircher et al., 2000, 2001) and the left insula (Sugiura et al., 2000) in visual self-face recognition has also been reported earlier. This structure was also attributed a role in the sustained attention to the representation of the own-face (Sugiura et al., 2000). These results are consistent with a right hemispheric dominance model of self-recognition and self-awareness (Keenan, Wheeler, et al., 2000, Keenan, Wheeler, & Ewers, 2003; Platek, Keenan, et al., 2004; Platek et al., 2006). We did not find any implication of the left fusiform although it has occasionally been previously reported. However, studies that reported activation in this region compared the self-face with an unfamiliar face (Kircher et al., 2000, 2001; Sugiura et al., 2005). Hence results of these studies could reflect a mere familiarity effect instead of a genuine self-effect. The processing of the colleague's face, compared with that of the self-face, showed differential activation in the superior temporal gyrus in both hemispheres and in the left precuneus. Activation was more reduced for the self-face than for the other familiar face in these regions. This result is consistent with several previous studies having reported that the activation is actually more reduced in the temporoparietal junction (Sugiura et al., 2005), in the left superior temporal gyrus and precuneus (Uddin, Kaplan, et al., 2005) for the self-face than for another familiar face. Sugiura and colleagues argued that these regions contain the representation of people's names and explained the greater deactivation in these regions when perceiving the self-face by covert naming that is more likely to occur when seeing familiar faces than when seeing one's face.

As for the recognition of the familiar bodies, we tentatively reported activation in the right cingulate gyrus and in a large frontal area on the right side when perceiving the self-body. This is quite consistent with results that we reported here above and with previous findings related to self-face processing (Keenan, Wheeler, & Ewers, 2003, Kircher et al., 2000; Platek, Keenan, et al., 2004; Platek et al., 2006; Sugiura et al., 2000; Uddin, Kaplan, et al., 2005). It is also interesting that, as it was the case for faces, the insula was implicated in self-body perception but on the *left* side. In order to prevent an identification based on other cues than the body shape itself, our participants' garment was standardized and it could be that the lack of strong activation for this contrast was due to the fact that person identification is less easy or less reliable from bodies than from faces leading to less sensible activation. Consistently with this hypothesis, reaction times indicated that participants were faster for faces than for bodies. However, the fact that our participants were all females may limit the generalisation of our results. Indeed, a recent study by Kurosaki et al. (2006) showed that some differences can be found between men and women when they are discriminating altered from intact versions of their own-body. They showed that, for women, the confrontation to an altered version of the own-body elicited activity in prefrontal and limbic areas (a parallel can be done with present observations) and for men, it rather elicited activity in the right occipital cortex. For the authors, this suggests that women would perceive distorted images of themselves by complex cognitivo-emotional processing whereas for men a more visuo-spatial processing is involved. However, contrary to us, these authors were interested in the processing of distorted images of oneself and they did not report data related to intact items. This makes hazardous any comparison between their study and the present one. Nevertheless, their findings related to gender differences should encourage further studies about familiar and self-body processing including males as well as females.

The last aim of this study was to investigate whether cerebral regions are activated by self-processing independently of the stimulus domain, i.e. regardless of whether a face or a body was processed. A comparison of the processing of self-related pictures with the processing of pictures related to another highly familiar person revealed an implication of the right anterior insula and of the right dorsal anterior cingulate. This implication of the anterior cingulate is in line with findings of a recent study by Platek et al. (2005). They showed that this region is at play during processing of self facial resemblance. Since this region is also implicated during the processing of face familiarity or self-referent information, they suggested that this region might be generally involved when making decisions about self-referential information. Our findings are also consistent with Northoff and Bermpohl (2004)'s thesis that the cingulate gyrus could play a role in abstract self-processing, that is, independent of the stimulus domain or of the sensorial modality. The activity found in the right anterior insula is also in line with previous studies investigating different aspects of self-processing and indicating that this structure is implicated in self-agency (Farrer & Frith, 2002), autobiographical episodic memory retrieval (Fink et al., 1996), self-face recognition or self-descriptive judgments (Kircher et al., 2000, 2001). The specific role of this structure remains to be investigated but present results as well as those of previous studies suggest that, like the anterior cingulate, the right anterior insula could play a general role in making decisions about oneself. The right hemispheric implication is also in agreement with patients studies showing that the condition of persons suffering from an alteration of the sense of self is principally underlain by brain damages localised in the right frontal lobe (for a review see Feinberg and Keenan, 2005).

A secondary aim of this study was to check which regions are implicated during face or during body processing. Comparisons of body shape or face processing with seeing a scrambled image indicated that faces and bodies seemed to recruit close but segregated areas of the occipital cortex (see Figure 1). This is in agreement with previous studies that identified distinct regions of the extrastriate cortex that are specifically devoted to faces (ventral occipital face area, OFA, Puce et al., 1996; Peelen & Downing, 2005) and bodies (extrastriate body area, EBA, Downing et al., 2001; Peelen & Downing, 2005). Visual analysis of Figure 1 also indicated a common implication of the right fusiform gyrus for faces and bodies. This is also consistent with recent studies (Peelen & Downing, 2005; Schwarzlose et al., 2005) which found such overlapping although distinct regions of the fusiform gyrus were associated with presentation of faces and bodies. In addition, as it has already been shown previously (Spiridon, Fischl & Kanwisher, 2006), although left and right hemispheres showed a similar pattern of activation with faces and bodies (FFA and EBA), the implicated areas seemed less extended on the left than on the right. However, these results have to be taken cautiously because the two stimulus domains were presented in two different sessions which certainly gave rise to a poor sensitivity.

From these results, it appears that after a partly segregated structural processing of the shape of faces and bodies in posterior areas, the distinction between self and others might be processed in more anterior regions. Self-related stimuli were specifically processed mainly in the right frontal gyrus and in the anterior insula compared with stimuli depicting another highly familiar person. In agreement with previous studies (for a review, see Northoff & Bermpohl, 2004), we found that specific areas in the right anterior insula and in the right dorsal cingulate gyrus are also devoted to integrative self-processing regardless of the stimulus domain.

Thus, our results suggest that posterior and anterior regions play different roles in person identification. Posterior regions (i.e., occipito-temporal cortex) seem to be involved, at a first level of processing, in the distinction of different aspects of persons (i.e., a rough classification as face or body). Indeed, our results indicated that these regions were differently recruited to process different body parts (i.e., the face alone *vs*. the headless body). The fusiform gyrus could then perform a more detailed structural encoding of stimuli (i.e., here the different body parts) and give a first assessment of the seen person's familiarity (see Rossion, Schiltz, & Crommelinck, 2003) before further processing. That could explain why we did not find activity in this region when we compared the processing of two highly familiar persons (and corollary why other studies comparing self-face recognition with unfamiliar face recognition did so). Regarding person identification from faces, the present hypothesis represents an intermediate view (see also Grill-Spector, Knouf, & Kanwisher, 2004) between the hypothesis that FFA simply allows to classify a stimulus as a face (detection hypothesis, see Kanwisher, McDermott, & Chun, 1997), and the other hypothesis that this area is involved in individual identification of faces (see Gauthier et al., 2000; Haxby, Hoffman, & Gobbini, 2000). In addition, our results are in agreement with studies that show that the FFA is involved in face processing but also during identification/sub-categorization of different classes of objects by experts (Xu, 2005; for reviews, see Tarr & Cheng, 2003; Tarr & Gauthier, 2000). Indeed, the fusiform gyrus was recruited during face as well as body processing, i.e. two different classes of "objects" that humans process with a relative expertise. At a later level of processing, anterior regions (i.e., mainly the frontal and superior temporal cortices, the anterior cingulate cortex and the anterior insula) may serve to distinguish different persons from each other and to access more abstract information about identity of familiar individuals (for instance people's names and semantic information about these persons). More specifically, the anterior insula and the anterior cingulate cortex would permit to distinguish oneself from others and give rise to an abstract representation of oneself that could possibly participate in maintaining a sense of self.

To conclude, this study showed that specific cortical regions, mainly the right frontal cortex and the insula, are implicated in visual self-recognition compared with visual processing of highly familiar and personally known persons. These results support the view (Keenan, Wheeler, et al., 2000, 2001; Platek, Keenan, et al., 2004) that the right frontal cortex is preferentially recruited during self-recognition. In addition, our data indicated, in agreement with the findings of several new recent studies (Downing et al., 2001, 2005; Peelen & Downing, 2005; Schwarzlose et al., 2005), that the occipito-temporal cortex is more or less recruited depending on whether a face or a body is perceived. Finally, our study indicated that posterior regions would be involved in an increasingly detailed structural representation of different aspects of a person, whereas anterior regions within the right hemisphere (i.e., the anterior insula and the dorsal anterior cingulate) would be implicated in distinguishing between the self and others and in a more abstract representation of the self.

Experimental procedure

Participants

Twenty right-handed female students from the University of Liège aged between 18 to 27 years (*M* = 22.1, *SD* = 2.3) participated. Participants were recruited by pairs so that each participant served as a colleague for another participant. Each participant had known her colleague for between 2 and 6.5 years (*M* = 4 years, *SD* = 1.3). They had no history of psychological or neurological disorders and had a normal or corrected-to-normal (with contact lens) vision. The study was approved by the Ethics Committee of the Faculty of Medicine and of the Faculty of Psychology of the University of Liège, and was performed in accordance with the ethical standards described in the Declaration of Helsinki (1964). All participants gave their informed consent prior to their inclusion in the study.

Materials

Each participant's face was photographed, in a frontal position, and with a neutral expression. The pictures were then cropped and resized to be 450 pixels wide X 600 pixels high (10° X 13.4° at a viewing distance of 90 cm) with the image manipulation software Gimp 2. We made two alterations of the face of each participant: the eyes were moved 16 pixels (0.35°) inwards or outwards (see Figure 5). These alterations were chosen to be plausible but easily detectable (Brédart & Devue, 2006). We also took a picture of each participant's body wearing the same white t-shirt and a pair of blue jeans. Shoes were digitally re-colored in black. These pictures were cropped and resized to be 350 pixels wide X 600 pixels high (7.8° X 13.4°). The face was hidden by a 100 X 100 pixels black square and the background wall was light grey. We also made two alterations on the body of each participant (using Morph Man 2000): the waist-to-hip ratio (WHR) was decreased or increased of 10% respectively by enlarging or reducing the width of the hips (see Figure 6).

These alterations were chosen to fit face alterations (i.e., affecting the horizontal dimension of a relevant part of the stimulus and giving rise to easily detectable but plausible novel configuration). Such alterations were thus performed on female bodies exclusively. Indeed, men's WHR is typically between 0.85 and 0.95 (Singh, 1995) and increasing this ratio would have produced stimuli showing grotesque body shapes with a WHR higher than 1. Each participant was presented with the mirror-reversed versions of her 6 pictures (one intact and two altered faces, one intact and two altered bodies) and the normal-oriented versions of the 6 pictures of her colleague. For each pair, the luminance of the 12 resulting pictures was equated with Matlab 6 to prevent any low-level differences among these pictures. In addition, the pictures of the intact face and body of each participant were scrambled (with Matlab 6, see Figure 5d and Figure 6d).

Procedure

Before being installed in the scanner, participants were presented 12 pictures: 3 pictures of their own face (the original one and the two altered versions), 3 pictures of their colleague's face, 3 pictures of their own body and 3 pictures of their colleague's body. The experimenter indicated whether each stimulus was intact or altered. The 'Stimulus appearance' factor hereafter refers to the intact *vs.* altered aspect of the stimulus while the 'Stimulus domain' factor defines whether a face or a body was presented. A pre-training (16 trials with faces and 16 trials with bodies) was administrated to illustrate the task to be performed in the scanner. The participants were then installed in the scanner. They hold a small keyboard in their right hand and stimuli were displayed on a black screen positioned at the back of the scanner, which the participant could comfortably see through a mirror fixed on the standard head coil.

We used an event-related paradigm within four different sessions. The two first sessions were the experimental sessions. Each one consisted of the presentation of the intact and altered versions of the pictures of the two members of the pair. In one of them, only faces were presented, and in the other, only bodies were presented (the presentation order of the two sessions being counterbalanced across participants). Within one session, each intact picture was presented 40 times and each altered picture was presented 20 times (for a total of 40, as there were two alterations per original picture). An experimental session was then composed of 160 trials presented at random. Null events consisted in random presentation of a white cross identical to the fixation cross (40 occurrences) during the session. The participants were instructed to press a key with their index finger if the picture was intact and another key with their middle finger if the picture was altered. Performing such an ‘intact-altered’ judgment implied that participants had first to identify the owner of the face/body to be able to give their response. They were allowed 2000 ms to respond. The picture stimulus disappeared immediately after pressing the response key (allowing some random variation between the successive presentation of two trials), followed by the presentation of a fixation cross for 1500 ms. When they did not respond in the imparted 2000 ms, a no-response was recorded. Before each of the two scanning sessions started, participants were again presented with all the corresponding pictures and performed a training of 16 trials. In the two first sessions, we were interested in directly contrasting self-processing from the processing of another highly familiar person. So, control items taking into account low level perceptual processes (such as scrambled figures) were not used, these low level processes being similar regardless of the kind of items presented.

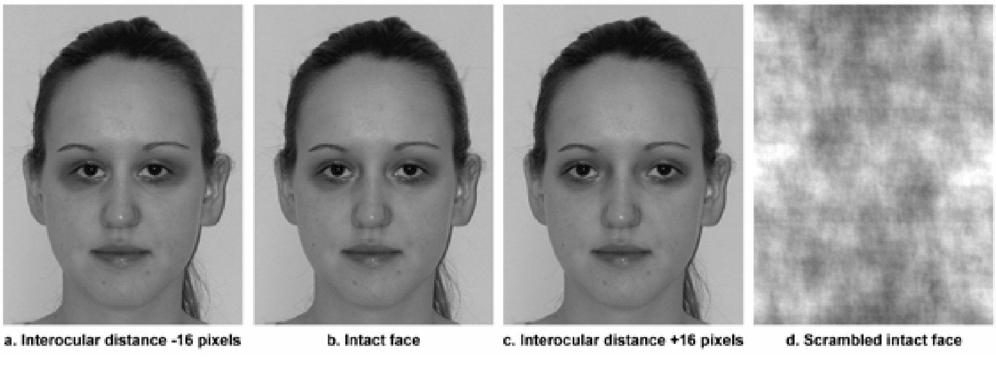

a. Interocular distance -16 pixels
b. Intact face
c. Interocular distance +16 pixels
d. Scrambled intact face

Figure 5. Sample of face stimuli from one participant. From the original picture (b) the eyes were moved inwards to decrease the interocular distance of 16 px (a) or outwards to increase the interocular distance of 16 px (c). For one of the two control sessions, the intact face was scrambled (d).

The two last sessions were the control ones. During each of these sessions, participants saw the intact picture (of their own face in one session, of their own body in the other one, the order being the same than that of the experimental sessions) 40 times and the scrambled version of this picture 40 times, in a random order. Each control session was thus composed of 80 trials. The pictures were presented for 2000 ms and were preceded by a red fixation cross for 750 ms. The participants' task was to attend to this fixation cross and to report an infrequent color change (the cross was yellow in 12.5% of the cases) by pressing a key. This procedure was used to maintain the participants' attention while they passively viewed the stimuli of interest. Here, self-referential items were compared with scrambled items in order to suppress low-level perceptual processes that are not specific to face or body identification.

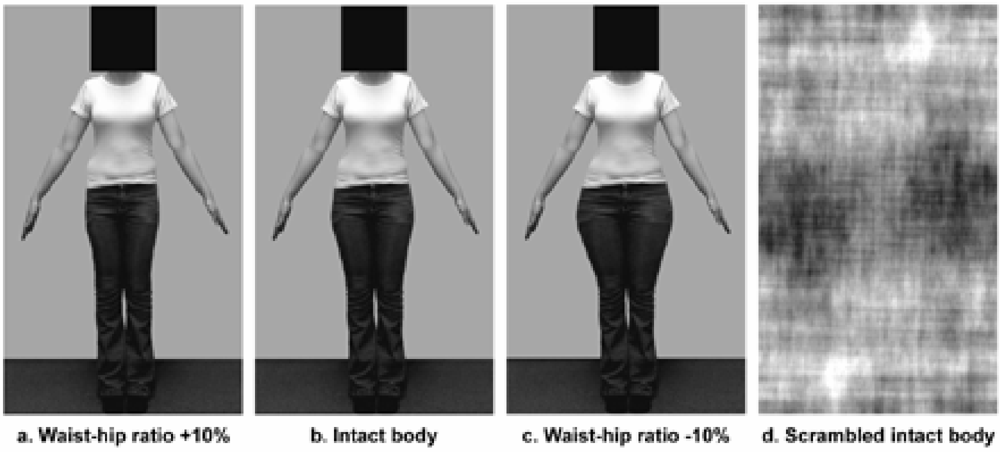

a. Waist-hip ratio +10%
b. Intact body
c. Waist-hip ratio -10%
d. Scrambled intact body

Figure 6. Sample of body stimuli from one participant. From the original picture (b) the hips were made thinner to increase the WHR of 10% (a) or wider to decrease the WHR of 10% (c). For one of the two control sessions, the intact body was scrambled (d).

MRI acquisition

Data were acquired on a 3Tesla scanner (Siemens, Allegra, Erlangen, Germany) using a T2* sensitive gradient echo EPI sequence (TR = 2,130 ms, TE = 40 ms, FA 90°, matrix size 64 X 64 X 32, voxel size 3.4 X 3.4 X 3.4 mm^3). Thirty-two 3-mm thick transverse slices (FOV 22 X 22 cm^2) were acquired, with a distance factor of 30%, covering the whole brain. Structural images were obtained using a T1-weighted 3D MP-RAGE sequence (TR = 1,960 ms, TE = 4.4 ms, FOV 23 X 23 cm^2, matrix size 256 X 256 X 176, voxel size 0.9 X 0.9 X 0.9 mm). In each experimental session, between 177 and 292 functional volumes were obtained. In each control session between 112 and 122 functional volumes were obtained. The first three volumes were discarded to account for T1 saturation. Head movement was minimized by restraining the participant's head using a vacuum cushion.

fMRI analyses

Data were preprocessed and analyzed using SPM2 software (Wellcome Department of Imaging Neuroscience). Preprocessing included motion correction, spatial normalization in MNI space and spatial smoothing using a Gaussian kernel of 8 mm full width at half maximum.

For each participant, brain responses were estimated at each voxel, using a general linear model. In each experimental session (face and body), events modeled transient responses to the two identities (self and colleague) and to the two stimulus appearances (intact or altered). Only brain responses for correct responses were entered in the matrix design.

In each control session (face and body), events modeled transient cerebral responses to the self identity for intact or scrambled items.

Delta functions representative of these trials types were convolved with the canonical hemodynamic response. The design matrix also included the realignment parameters to account for any residual movement-related effect. Two contrasts were performed in order to explore the main effect of the presented picture (intact *vs*. scrambled) in each of the two control sessions (face *vs.* body, contrasts 1 and 2). In experimental sessions, we were interested in cerebral areas involved in the processing of original self-related pictures in comparison with that of pictures depicting another highly familiar person. Seven linear contrasts were performed by using intact items only. These included two contrasts assessing the effect of the Stimulus domain (face *vs.* body): the first explored the effect of intact face processing in comparison with the processing of intact bodies (contrast 3), and the second contrast assessed the effect of intact body processing in comparison with intact face processing (contrast 4). The next four contrasts were carried out to compare (i) the effect of self-face processing relative to the processing of another highly familiar face (self *minus* other, contrast 5, and other *minus* self, contrast 6), and (ii) the effect of own-body processing relative to the processing of another highly familiar body (self *minus* other, contrast 7, and other *minus* self, contrast 8). Finally, the effect of self-processing regardless of the Stimulus domain (face *and* body) in comparison with another familiar person was determined (contrast 9). No statistical inference was made at this level (fixed effects). Summary statistic images were thresholded at $p < 0.9$ (uncorrected) and these images were further smoothed (6-mm FWHM Gaussian kernel). They were then entered in a second-level analysis, corresponding to a random effects model, in order to account for inter-subjects variance in each contrast of interest. One-sample t tests assessed the significance of the effects. The resulting SPM{T} maps were thresholded at $p < 0.001$. Statistical inferences were performed at the voxel or cluster level at $p < 0.05$ corrected for multiple comparisons (Bonferroni corrections) across the entire brain volume. Alternatively, when previous studies led us to expect that changes in brain responses would occur in certain specified areas, a small volume correction (Worsley, 1996) was computed on a 20 mm maximum radius sphere around the average coordinates published for the corresponding relevant location. However, for contrasts about which there was no clear a priori hypothesis because of a lack of previous literature (this is particularly true for the visual recognition of <u>familiar</u> bodies), we tentatively reported activation at a threshold of $p < 0.001$, uncorrected for multiple comparisons.

A priori locations of interest

The following *a priori* locations of interest were used for small volume corrections, based on published coordinates in the literature about self-face recognition and self-processing (judgment of adjectives/sentences as self-descriptive and judgment of actions as self generated). Regarding the general self-processing, independently of the Stimulus domain, these regions concerned mainly the medial/right prefrontal cortex, the right anterior cingulate, the bilateral insula and the bilateral precuneus. As for self-face recognition, the a priori locations of interest were chosen from literature using contrasts as comparable to ours as possible (own face *minus* other highly familiar face and conversely for the reversed contrast). These regions concerned primarily the right inferior frontal cortex and the left fusiform gyrus. Concerning the a priori locations of interest related to the processing of faces and bodies during the control session, they referred to studies comparing the processing of faces and bodies, respectively, to that of other kind of materials (i.e., tools, Peelen & Downing, experiment 1, 2005; scrambled controls, Peelen & Downing, experiment 2, 2005; letters or textures, Puce, et al., 1996). All stereotactic coordinates refer to the MNI space. When a single coordinate refers to several studies, it corresponds to the centroïd of all the coordinates reported in these studies. The a priori locations of interest were the following ones:

General effect of self-processing: right/medial prefrontal cortex [10, 50, 20; 10, 53, 5] (Fossati et al., 2003; Kelley et al., 2002), right anterior cingulate gyrus [6, 35, 6] (Craik et al., 1999), anterior insula [-36, -2, 2; 40, 8, 3] (Farrer & Frith, 2002), precuneus [-4, -56, 34; 6, -63, 36] (Kircher et al., 2000, 2002; Ruby & Decety, 2001), left inferior frontal gyrus [-39, 9, 16] (Craik et al., 1999; Kircher et al. 2002), left superior frontal gyrus [-11, 21, 59] (Ruby & Decety, 2001; Seger et al., 2004).

Effect of self-face recognition (self-face *minus* other familiar face processing): right inferior frontal gyrus [45, 25, 14] (Platek, Keenan, et al., 2004; Uddin, Kaplan, et al., 2005), left inferior frontal gyrus [-38, 25, 23] (Kircher et al., 2000), right superior frontal gyrus [26, 34, 34; 20, 16, 56] (Platek et al., 2006), right middle frontal gyrus [26, -12, 46] (Platek et al., 2006), right medial frontal gyrus [6, 48, -12] (Platek et al., 2006), left middle temporal gyrus [-52, 4, -16; -58, -6, -4] (Platek et al., 2006), left fusiform gyrus [-14, -83, -18] (Kircher et al., 2001), right inferior parietal lobule [50, -62, 40; 64, -24, 50; 42, -34, 38] (Platek et al., 2006; Uddin, Kaplan, et al., 2005).

Effect of other familiar face recognition (other familiar face *minus* self-face processing): left anterior cingulate [-2, 24, -2] (Platek et al., 2006), left superior temporal gyrus [-54, -42, 12] (Uddin, Kaplan, et al., 2005), right middle temporal gyrus [70, -12, -16] (Uddin, Kaplan, et al., 2005), precuneus [0, -48, 38] (Uddin, Kaplan, et al., 2005).

General effect of face recognition (face *minus* other material processing): right fusiform gyrus [39, -44, -22; 30, -55, -24; 31, -55, -24] (Peelen & Downing, 2005, Puce et al., 1996), left fusiform gyrus [-38, -60, -26; -39, -54, -28] (Puce et al., 1996), right ventral occipital cortex [39, -65, -25] (Peelen & Downing, 2005), right occipitotemporal/inferior occipital sulci

[36, -67, -22; 38, -63, -23] (Puce et al., 1996), bilateral lateral neocortex [47, -66, -4; 43, -67, -8; -40, -76, -7] (Puce et al., 1996).

General effect of body recognition (body *minus* other material processing): right fusiform gyrus [40, -43, -21; 41, -38, -25] (Peelen & Downing, 2005), bilateral inferior temporal sulcus [45, -67, -1; 47, -64, 3; -49, -77, 6] (Peelen & Downing, 2005).

Acknowledgements

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Chapter 6

ATTENTION TO SELF-REFERENTIAL STIMULI: CAN I IGNORE MY OWN FACE?

Christel Devue and Serge Brédart (in press). *Acta Psychologica*.

Abstract

Auto-referential materials (i.e., the own name) have been described as particularly prone to capture attention. Some recent studies have questioned this view and showed that these own name effects are temporary and appear only in specific conditions: when enough resources are available (Harris & Pashler, 2004) or when the own name is presented within the focus of attention if it is a task-irrelevant stimulus (Gronau et al., 2003). In the present study, a stimulus that is unique to each individual was used: the self-face. In Experiment 1, the self-face produced a temporary distraction when presented at fixation during a digit-parity task. However, this distraction was not different from that triggered by another highly familiar face. In Experiment 2, the self-face failed to produce interference when presented outside the focus of attention. These results confirm recent findings showing that auto-referential materials do not automatically summon attention and have a distractive power only in specific conditions.

Introduction

Since the late fifties, self-referential stimuli have been described as particularly important with regard to their capacity to grab attention by comparison with other stimuli. This claim emerged from a famous study by Moray (1959). Using the method of shadowing during a dichotic listening task, Moray (1959) found that 4 participants out of 12 (33%) remembered that they had heard their own name at its first presentation to the unattended ear while they were shadowing (i.e., repeating aloud) a message presented to the other ear. On the contrary, a short list of neutral words presented many times to the unattended ear showed no trace of being remembered. This suggested that some high-priority important stimuli can capture attention because of their meaning. However, there was no way to exclude the possibility that subjects from time to time shifted their attention to the to-be-ignored message (see Lachter, Forster, & Ruthruff, 2004). More evidence for some "own name effects" has also been found in various studies using different procedures. For instance, in a visual analogy of the Moray's procedure, Wolford and Morrison (1980) showed that when instructed to make a parity judgment on two digits flanking a to-be-ignored word, a higher proportion of participants subsequently reported that they had seen their own name in comparison with words presented the same number of times during the experiment. Shapiro's team later showed that the own name is particularly resistant to the attentional blink (Shapiro, Caldwell, & Sorensen, 1997) and to repetition blindness (Arnell, Shapiro, & Sorensen, 1999). In addition, Mack and Rock (1998) found that almost all of their participants (88%) detected their own name when presented under conditions of inattention in the inattentional blindness paradigm. By comparison, only 65% of participants detected another first name and 50% of participants detected very frequent words in the English language (e.g., "house"). Using a visual search task, Mack and Rock (1998) also showed that, contrary to other names, the own name pops out of a display of up to 12 items.

All these studies investigated the attentional properties of the own name. However, the name (i.e., the first name as well as the last name) is a property that we may share with other people. By contrast, the face is a unique self-referential characteristic (with the exception of twins) and hence constitutes a better way to investigate the specificity of self-referential stimuli. However, few studies (Brédart, Delchambre, & Laureys, 2006; Laarni, Koljonen, Kuistio, Kyröläinen, Lempiäinen, & Lepistö, 2000; Ninomiya, Onitsuka, Chen, Sato, & Tashiro, 1998; Tong & Nakayama, 1999) investigated the attentional properties of the self-face. Recently, using a face-name interference paradigm, Brédart et al. (2006) found that the self-face flanking a classmate's name produced a stronger interference on the processing of this name than in the reverse situation where a classmate's face flanked the participant's own name. This suggests that the self-face also has some attention-grabbing capacity. Tong and Nakayama (1999), in a visual search task, demonstrated that the self-face was more quickly detected among distractors than strangers' faces even when presented in atypical orientations and after hundreds of trials. Several ERP or PET studies also found specific electrophysiological and neuronal responses associated with attention to the self-face by comparison with other unfamiliar faces (Gray, Ambady, Lowenthal, & Deldin, 2004; Ninomiya et al., 1998; Sugiura et al., 2000; Sui, Zhu, & Han, 2006; Tanaka, Curran, Porterfield, & Collins, 2006) or familiar faces (Sui et al., 2006). All these findings suggest that important stimuli may benefit from specific attention-grabbing capacities. Taken together, these results seem in favour of a late selection theory of attention (Deutsch & Deutsch, 1963) because they suggest that the meaning and significance of some stimuli can determine their selection by attention. However, many studies used neutral words, unfamiliar faces or names as control stimuli. Hence, these results might just reflect a familiarity effect rather than a genuine "self-effect". That might weaken the argument in favour of a late selection theory of attention because this could indicate that familiarity rather than meaning determines the attentional selection.

In addition, recent research has seriously questioned the specificity of self-referential stimuli by suggesting that such stimuli are not really special and do not benefit from particular attention-grabbing capacities. A study by Bundesen, Killingsbæk, Houmann, and Jensen (1997) challenged previous findings with respect to the attention-grabbing capacities of the own name. They used displays composed of four names, two written in red (targets to be reported) and two written in white (distractors to be ignored). The participant's name appeared on some trials either as target either as distractor. Results showed that the own name did not cause more interference than other names when it was a distractor suggesting that it does not automatically grab attention. Laarni et al. (2000) found that when participants had to perform a matching task on two faces presented at foreground while ignoring the background composed of a matrix of faces among which the participant's own face or a celebrity face (the Finnish President) was presented on some trials (i.e., critical trials), only 18% of participants reported that they had seen their own face during the task and the performance was similar for both familiar faces. These results could be interpreted in terms of an early selection of attention occurring at an early stage of processing (Broadbent, 1958) preventing the processing of significant stimuli when they were already discarded from the perceptual process by the properties of their low level features (e.g., irrelevant colour, irrelevant background location, see also Bundesen et al., 1997).

Finally, some studies using the own name moderated findings presented here above by showing that some "self-effect" can occur but only when specific conditions are fulfilled. For instance, Kawahara and Yamada (2004) replicated Bundesen et al. (1997)'s findings but additionally showed, using an adapted version of the attentional blink paradigm, that the own name only attracted attention when participants were set to identify target names whereas it did not when participants were set to find a target colour. Similarly, using a Stroop-like task Gronau, Cohen, and Ben-Shakhar (2003) found that the own name attracted attention when it was presented centrally within the participant's attentional focus. However, when it was presented peripherally it attracted attention only when it was task relevant but not when it was task irrelevant. Harris, Pashler, and Coburn (2004) also call Mack and Rock (1998)'s visual search findings into question by showing that even if the participant's own name is detected more rapidly than other names, the search slopes they obtained were not flat enough to claim that the own name pops out. In another experiment based on the paradigm designed by Wolford and Morrison (1980), Harris and Pashler (2004) showed that the presentation of the own name can cause a distraction and slow down reaction times on a digit-parity task by comparison with neutral words on condition that enough capacity is available. In this case, however, the distraction is only present during the first occurrences of the own name and the response quickly habituates. Moreover, the own name did not show special attention grabbing property when display loads were more substantial. Taken together, this set of results suggests that the first occurrences of one's own name may provoke an involuntarily shift of attention when the perceptual load of one's ongoing activity is low and enough capacity is available for one's name to be perceived, but that it rapidly loses its attention grabbing character.

From this overview of the literature, it remains unclear whether or not self-referential materials have specific attention-grabbing capacity. Moreover, controls used to determine whether these stimuli have special attention-grabbing capacities were not always the most appropriate ones and some confounding factors such as familiarity, frequency of use or emotional valence could have interfered. The aim of the present study was to evaluate the distractive potency of an extremely distinctive self-significant stimulus, i.e. the self-face, and in the meantime disentangling the potential effect of stimulus familiarity. In Experiment 1, we tested whether one's own face is harder to ignore as a distractor than other unfamiliar faces. If results found in the Harris and Pashler (2004) study can be generalised from the own name to other self-significant stimuli, it was expected that the first presentation of the participants' face would produce a momentary distraction. To determine how much such effect was specific to one's own face, distraction due to the presentation of another personally familiar face (the face of a participant's classmate) was also evaluated.

In the Harris and Pashler (2004) study, distractors were presented centrally, i.e. between the items to be processed for the primary task. Gronau et al. (2003) demonstrated that the presentation of one's name outside the focus of attention did not interfere with a primary task if one's name was not relevant to this primary task. Hence, it was predicted that the presentation of the participant's own face as an irrelevant flanking distractor would produce no disruption of the primary task at all. This point was addressed in Experiment 2.

EXPERIMENT 1

The experiment used the digit-parity task described by Wolford and Morrison (1980) and Harris and Pashler (2004), i.e. a task in which participants indicated whether two simultaneously presented digits had the same parity or not. By analogy with the Harris and Pashler study, during the first block of trials, familiar faces (either one's face or a classmate's face) were presented infrequently. In the second block of trials familiar faces were presented on half of the trials.

Method

Participants

A total of 48 undergraduate students (mean age = 20; 30 women) volunteered. They had all known their same-gender classmate for at least 2 years. Participants were recruited by pairs so that each participant served as the classmate for the other participant.

Materials and stimuli

Displays were presented on a monitor controlled by a PC computer. They consisted of two digits flanking a face and were viewed at a distance of 56 cm controlled by means of a chin rest. The digits subtended 0.7° by 0.5° of visual angle, were spaced 4° apart, and located 2° from fixation each. They were written in black against a grey background. All face stimuli were greyscales images of full-frontal views of faces without facial hair or glasses. The picture of the participant’s own face was presented in a mirror-reversed orientation, i.e. the view in which we typically see our own face. The pictures were centred at fixation and subtended 4.1° by 3.3° of visual angle (see Fig.1b).

Procedure

The experiment consisted of two blocks of 48 trials each. In Block 1, the participant’s own face and the face of the participant’s classmate were presented once each. Half of the participants saw their own face on Trial 29 and their classmate’s face on Trial 39, the other half saw these two familiar faces in the reverse order. Pictures of unfamiliar faces were shown on the other trials. Each unfamiliar face appeared once only. In Block 2, the participant’s face appeared on 12 trials, the classmate’s face appeared on 12 trials and 24 new unfamiliar faces appeared on the remaining 24 trials. Faces were presented randomly except that the same face could not be shown twice successively.

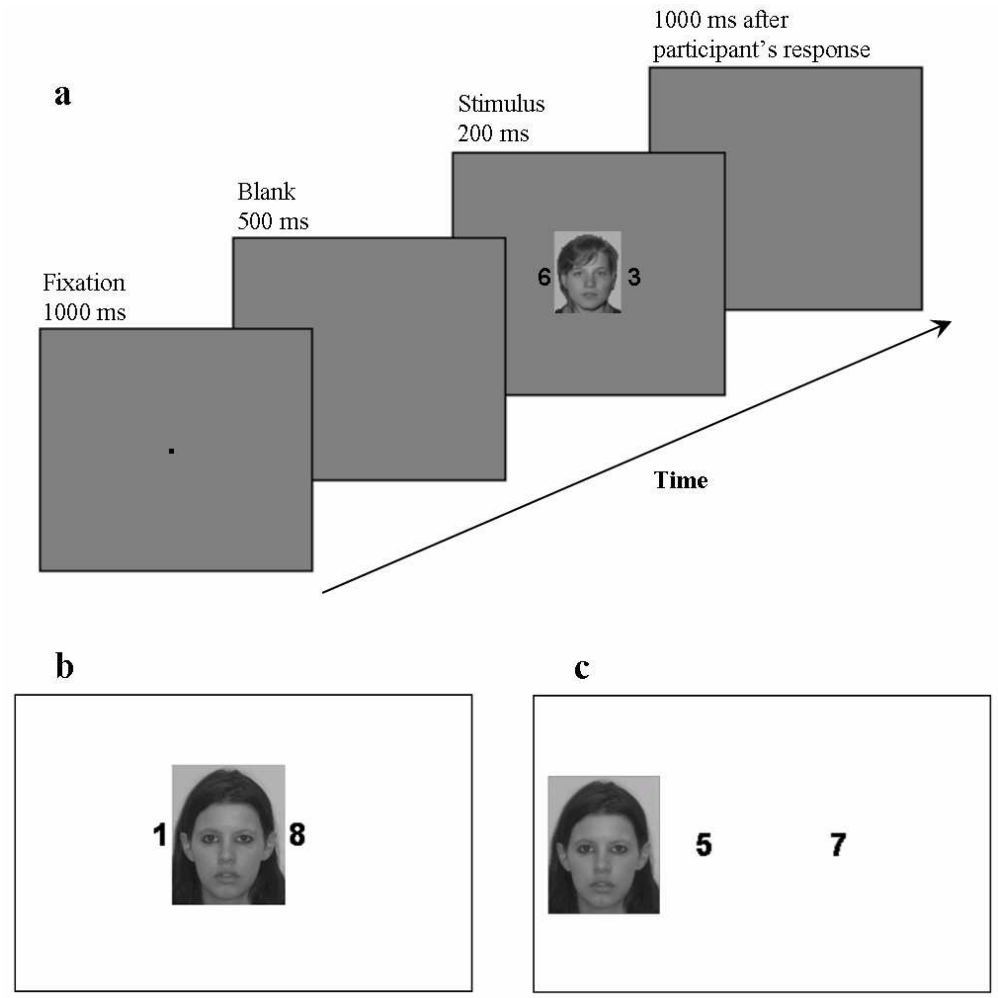

Figure 1. (a) Illustration of the time course of a single trial in the two experiments (the stimulus display represented here corresponds to displays in Experiment 1); (b) in Experiment 1, faces were presented at fixation between two digits; (c) in Experiment 2, faces were presented at periphery, randomly on the left or on the right (here on the left) of two digits.

Participants were instructed to focus on the digit-parity task and ignore the faces. Each trial began with a fixation point (diameter = 0.2 degrees) presented in the centre of fixation for 1 s. The point was followed, after 500 ms, by a 200-ms (unmasked) exposure of the digits and face. Half of the participants pressed the “C” key of a computer keyboard if the digit parity matched, and otherwise pressed the “N” key. These keys were reversed for the other participants. A 1-s interval separated successive trials (see Fig.1a).

Results

Reactions times

Data of 15 participants who made errors on Trial 29 or 39 were discarded.

Block 1. A mixed two-way 2 (Order: self-classmate, classmate -self) by 5 (Trial: 20 to 28, 29, 30 to 38, 39, 40 to 48) ANOVA with repeated measures on the last factor was conducted on reaction times (RTs). There was a significant effect of Trial, $F(4,124) = 8.32$, $p = 0.00001$. HSD Tukey post-hoc indicated a significant elevation on the first two trials in which a familiar face was presented by comparison with preceding and following trials, all ps < 0.05. There was no significant effect of Order, $F(1,31) < 1$, and no significant interaction, $F(4,124) < 1$ (see Fig.2a).

Block 2. A one-way ANOVA with Identity (self, classmate, unfamiliar) as within-subject factor was conducted on RTs. There was a significant effect of Identity, $F(2,64) = 3.28$, $p = 0.04$. HSD Tukey post-hoc indicated that the difference between the RTs in the ‘self-face’ condition ($M = 1070$ ms) and the RTs in the ‘unfamiliar face’ condition ($M = 1002$ ms) was marginally significant, $p = 0.058$. In addition, RTs when the classmate was presented ($M = 1062$ ms) tended to be slower than RTs when an unfamiliar face was presented, $p = 0.10$. Finally, there was no significant difference between the ‘self-face’ condition and the ‘classmate’s face’ condition, $p = 0.96$ (see Fig.2b). Data of Block 2 were then split in 2 parts to examine separately the pattern of performance on the first and second halves of trials (see Fig.2c).

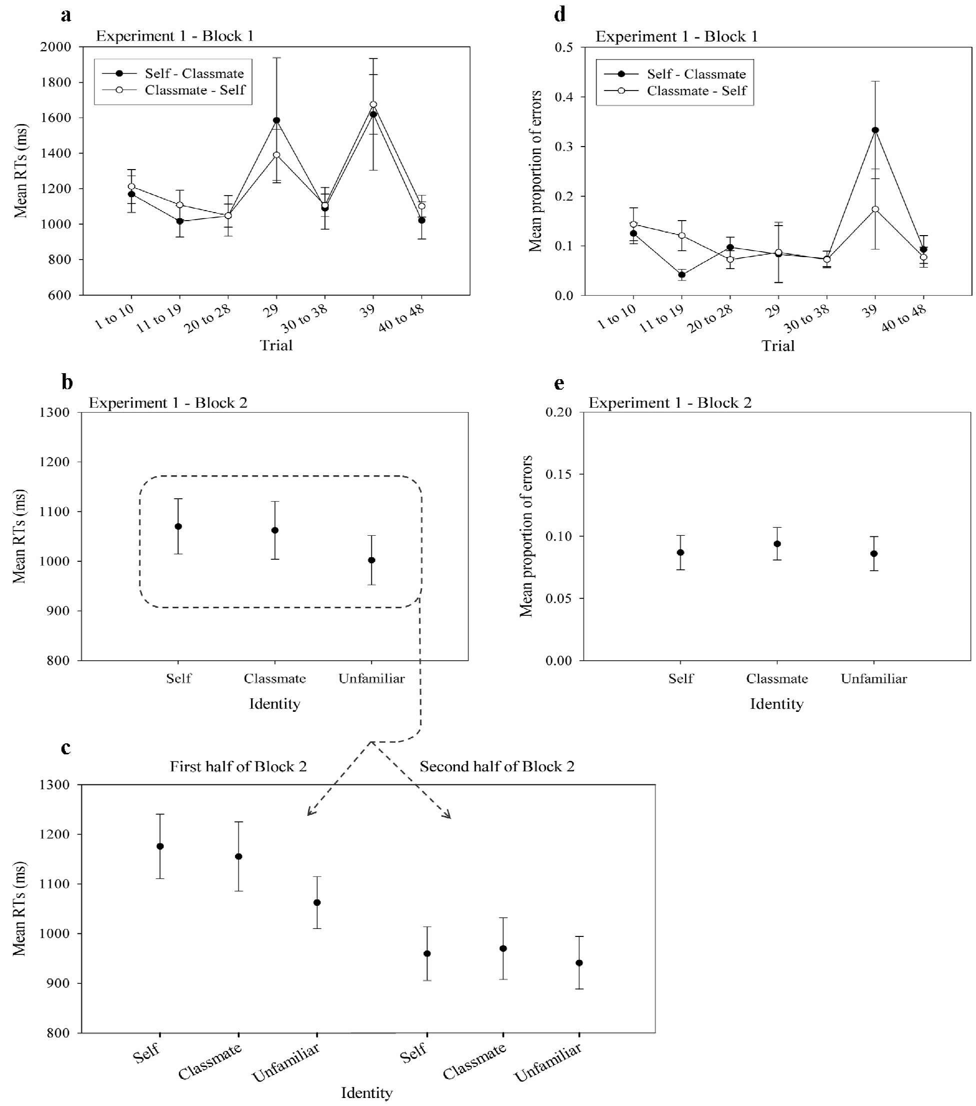

Figure 2. Results of Experiment 1: (a) Mean reaction times (RTs) and (d) mean error rates to the digit-parity task as a function of the order of presentation of the familiar faces in Block 1; familiar distractor faces appeared on trials 29 and 39. (b) Mean RTs and (e) mean error rates as a function of the Identity of the distractor face presented in Block 2. (c) Mean RTs as a function of the distractor face's Identity presented on the first and the second halves of Block 2. Error bars represent the standard error of the mean.

The analysis of RTs during the first half of Block 2 confirmed the above effect of the Identity, even if the difference was only marginally significant, $F(2,64) = 2.99$, $p = 0.058$. Conversely, the analysis of RTs during the second half of Block 2, did not reveal any effect of the Identity, $F(2,64) < 1$.

Error rates

Data of one participant who misunderstood the instructions were discarded (this participant responded to 26 out of 96 trials only).

Block 1. A mixed two-way 2 (Order: self-classmate, classmate -self) by 5 (Trial: 20 to 28, 29, 30 to 38, 39, 40 to 48) ANOVA with repeated measures on the last factor was conducted on error rates. There was a significant effect of Trial, $F(4,180) = 4.97$, $p = 0.0008$. HSD Tukey post-hoc indicated that when a familiar face was presented for the second time ($M = 25.4\%$ on trial 39), error rates were higher by comparison with preceding ($M = 8.3\%$ for trials 20 to 28 and $M = 7.1\%$ for trials 30 to 38) and following trials ($M = 8.5\%$ for trials 40 to 48) and by comparison with trial 29 ($M = 10.6\%$), all *p*s <0.02. There was no significant effect of Order, $F(1,45) = 1.22$; $p = 0.27$, and no interaction, $F(4,180) < 1$ (see Fig.2d).

Block 2. A one-way ANOVA with Identity (self, classmate, unknown) as within-subject factor was conducted on error rates and showed no significant effect, $F(2,92) < 1$ (see Fig.2e).

Discussion

Present results indicate that the self-face, like the own name, can produce a distraction. Like the own name, however, the self-face has no enduring attention grabbing capacity as the response habituates after a few presentations. In addition, the pattern of interference produced by the self-face and by the other highly familiar face was similar both in Block 1 and Block 2. The distraction produced by the two familiar faces impacted both dependent measures but was stronger on reaction times than on error rates. This suggests that the irrelevant presence of a familiar face mainly slows down the processing of the task-relevant items (i.e., the digits) but has a more limited effect on response accuracy. The second experiment examined the effect of the presentation of a familiar face (i.e., the self-face or the classmate's face) outside the focus of attention. It was predicted that the presentation of the self-face as an irrelevant flanking distractor would produce no disruption of the digit parity task at all (see Gronau et al., 2003).

EXPERIMENT 2

Method

Participants

A total of 48 undergraduate students (mean age = 21; 20 women) volunteered. They had all known their same-gender classmate for at least 2 years. Participants were recruited by pairs so that each participant served as the classmate for the other participant.

Stimuli and procedure

Experiment 2 was identical to Experiment 1 except that faces were presented in a flanking position instead of a central position. Faces were randomly presented on the left side of the left digit or on the right side of the right digit so that the centre of the picture was 5° from fixation (see Fig.1c).

Results

Data of 2 participants could not be collected entirely (1 because of technical reasons and 1 because the participant felt uncomfortable during the experiment) and were discarded from all analyses.

Reaction times

Data of 8 other participants who made errors on Trial 29 or 39 were discarded.

Block 1. A mixed two-way 2 (Order: self-classmate, classmate -self) by 5 (Trial: 20 to 28, 29, 30 to 38, 39, 40 to 48) ANOVA with repeated measures on the last factor was conducted on RTs. There was no significant effect of Trial, $F(4,144) = 1.02$, $p = 0.40$, no significant effect of Order, $F(1,31) < 1$, and no significant interaction, $F(4,124) < 1$ (see Fig.3a).

Block 2. A one-way ANOVA with Identity (self, classmate, unfamiliar) as within-subject factor was conducted on RTs and showed no significant effect, $F(2,74) = 2.28$, $p = 0.11$ (see Fig.3b). Nonetheless, as the pattern of performance was quite similar to that observed in Block 2 of Experiment 1 (see Fig.2b and Fig.3b) we split data of Block 2 in 2 parts to examine separately the pattern of performance on the first and second halves of trials. The analysis of RTs during the first half of Block 2 revealed a marginal effect of Identity, $F(2,74) = 3.911$, $p = 0.0504$. HSD Tukey post-hoc indicated that the difference between the RTs in the 'classmate's face' condition (M = 1122 ms) and the RTs in the 'unfamiliar face' condition (M = 976 ms) was significant, $p = 0.039$. RTs in the 'self-face' condition (M = 1045 ms) did not differ from RTs in the 'classmate's face' condition, $p = 0.39$, or in the 'unfamiliar face' condition, $p = 0.47$ By contrast, the analysis of RTs during the second half of Block 2 did not show any effect of Identity, $F(2,74) = 1.245$, $p = 0.29$ (see Fig.3b).

Error rates

Block 1. A mixed two-way 2 (Order: self-classmate, classmate-self) by 5 (Trial: 20 to 28, 29, 30 to 38, 39, 40 to 48) ANOVA with repeated measures on the last factor was conducted on error rates. There was no significant effect of Trial, $F(4,176) < 1$, no significant effect of Order, $F(1,44) < 1$, and no interaction, $F(4,180)=1.32$; $p=0.27$ (see Fig.3d).

Block 2. A one-way ANOVA with Identity (self, classmate, unknown) as within-subject factor was conducted on error rates and showed no significant effect, $F(2,90) < 1$ (see Fig.3e).

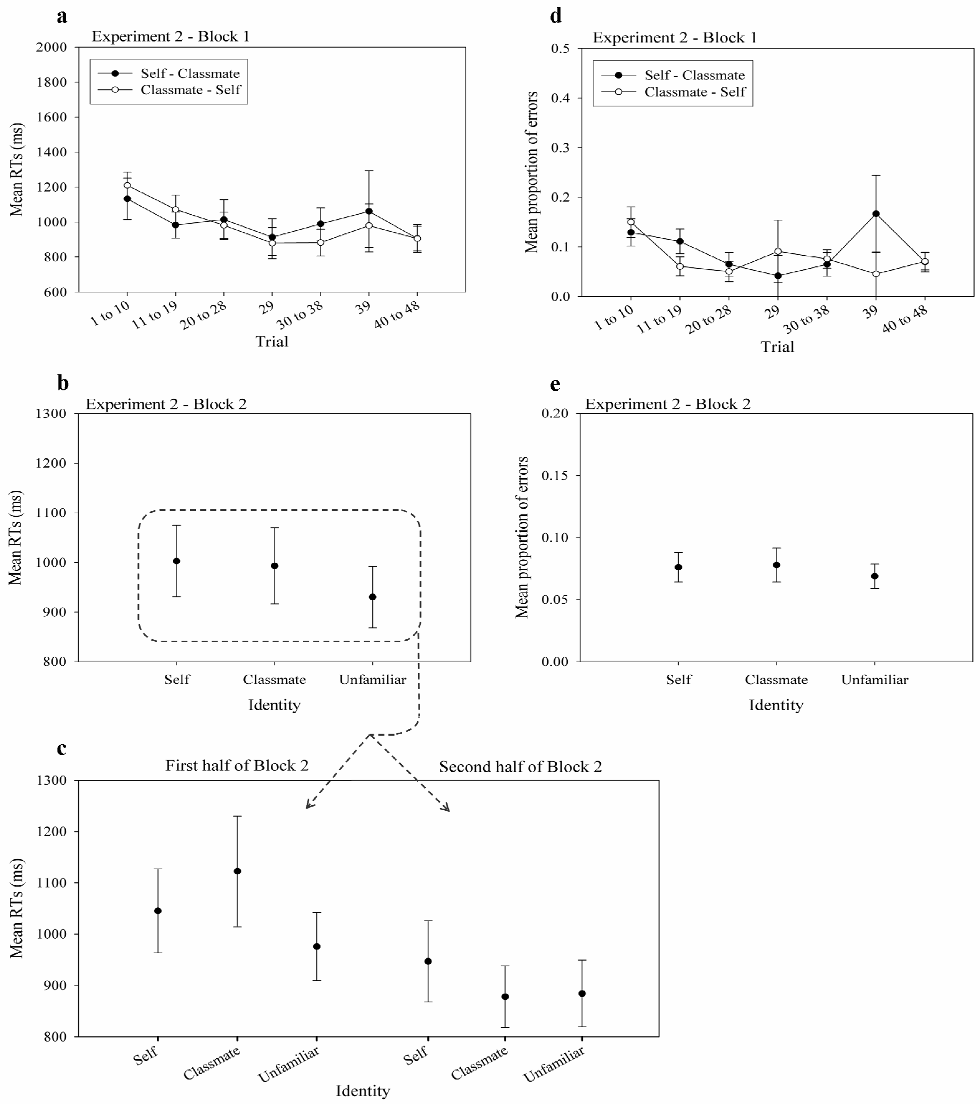

Figure 3. Results of Experiment 2: (a) Mean reaction times (RTs) and (d) mean error rates to the digit-parity task as a function of the order of presentation of the familiar faces in Block 1; familiar distractor faces appeared on trials 29 and 39. (b) Mean RTs and (e) mean error rates as a function of the Identity of the distractor face presented in Block 2. (c) Mean RTs as a function of the distractor face's Identity presented on the first and the second halves of Block 2. Error bars represent the standard error of the mean.

Discussion

In agreement with previous studies using the own name (Gronau et al., 2003), present results indicate that the self-face presented outside the focus of attention and irrelevantly for the ongoing task produces no distraction in Block 1 or in Block 2 overall, as reflected by both reaction times and error rates. However, a complementary analysis of Block 2 indicated that the facial identity marginally affected reaction times on the first half of trials. Here, the distraction was due to the processing of the classmate's face. Yet, as in Experiment 1, this effect disappeared in the second part of Block 2. This might indicate that after a few dozen of trials, when participants master the digit-parity task, they start shifting their attention at periphery and process the distractor faces. These shifts produce a weak interference effect that is not strong enough to overall affect performance in Block 2 and that habituates quickly. By contrast, in Block 1 the two appearances of the familiar faces did not interfere with the digit-parity task, probably because at that time the participants' attentional resources are still devoted to the digit-parity task. This small effect of familiar faces irrelevantly presented at periphery might seems at odds with Gronau et al. (2003)'s findings. However, this effect appeared lately in the experiment, lasted a very limited number of trials and was detected only through post-hoc analyses in the absence of a main effect of Identity. More importantly, the occurrence of this effect indicates that facial identity was perceivable at this eccentricity. In other words, the non-occurrence of interference effect in Block 1 cannot be attributed to a lack of perception of peripheral distractor faces.

General discussion

Present results indicate that the self-face, a particularly distinctive feature of the self, has no enduring distractive power compared with unfamiliar faces when it is presented at fixation, within the observer's attentional focus. Indeed, the self-face was only momentarily more distractive than unfamiliar faces. In addition, crucially the self-face was never consistently more distractive than that of another familiar person. Therefore, present results suggest that the allocation of attention was temporarily driven by the high familiarity of the to-be-ignored distractor faces rather than by the self-referential properties of the self-face. Yet, and contrary to the participant's name which may be shared by other individuals, the participant's own face is exclusively self-referential. Thus, one might have expected that it is even more likely than one's own name to attract attention by comparison with other faces. However, the present study demonstrates that one's own face is not an exceptional kind of stimulus since it rapidly loses its attention grabbing character. The present study extends Harris and Pashler (2004)'s work by showing that even a unique self-referential stimulus such as one's own face is not a potent distractor, at least when its presentation is not related with the ongoing task.

Moreover, in the present study, the self-face did not elicit reliable distraction effect when it was presented outside the focus of attention. This result is consistent with Gronau et al.'s (2003) study reporting that the participant's own name did not produce any distraction when presented outside the focus of attention and irrelevantly to the ongoing task. Nonetheless, our data indicated that participants temporarily shifted their attention towards peripheral faces once they mastered the digit-parity task. Importantly, the observation that the capacity of the familiar faces to provoke a distraction was dependent upon their location within the focus of attention indicates that this distraction is not due to an automatic capture of attention (see also Bundesen et al., 1999). Indeed, in Experiment 1 the central location of the faces between the two target digits forced participants to attend to the distractor faces (despite of the instruction) in order to perceive the two digits. By contrast, in Experiment 2, there was no need to attend to the distractor faces presented at periphery in order to process the target digits. Our results indicate that in this case participants successfully followed the instruction to ignore the faces in the first part of the experiment since the presentation of the familiar faces did not affect reaction times. In the second part of the experiment, however, they apparently temporarily shifted their attention towards peripheral faces. Rather, present findings suggest that familiar faces hold attention and elicit a transient difficulty to disengage attention only once they are attended[6], as in Experiment 1 and in the second part of Experiment 2 (see Fox, Russo, Bowles, & Dutton, 2001, for similar findings with threatening words; see also Weierich, Treat, & Hollingworth, in press, for a recent

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[6] We thank Jan Theeuwes for this suggestion.

review on the distinction between capture and retention of attention in anxiety). This hypothesis should be addressed more precisely and with paradigms allowing a clear distinction between these two components of capture and retention of attention in future work. Note that the digit-parity task we used is a quite demanding task. Harris and Pashler (2004)'s study showed that the attention grabbing capacity of one's own name depended on the amount of available resources. It is possible that a less demanding task would have allowed more substantial shifts of attention towards the peripheral distractor faces. This should also be addressed in future work.

In sum, present result does not support the widespread claim that self-referential stimuli or information important to the participant automatically summon attention. Yet, such a claim is still viewed as evidence for the late selection theory of attention even in recent cognitive psychology textbooks (e.g., Smith & Kosslyn, 2007; Solso, MacLin, & MacLin, 2005; Sternberg, 2006). Moreover, the present results, as well as those of Harris and Pashler (2004)'s study, stress that the response to one's own face or one's own name habituates very rapidly. This finding has important practical and clinical implications. Indeed, recent neuropsychological research used self-referential stimuli such as the patients' own name in order to assess residual awareness of the environment in non-communicative brain-damaged patients (i.e., patients in a vegetative or in a minimally conscious state). In such studies, properties of a patient's brain responses (e.g., ERPs) elicited when hearing her/his own name is supposed to inform us about the perception of this stimulus in the environment (Perrin et al., 2006; see also Holeckova, Fischer, Giard, Delpuech, & Morlet, 2006; Perrin et al., 2005). The fact that responses to self-referential may habituate quickly has not been addressed in such studies, presumably because, again, it was assumed that self-referential materials automatically grab attention (e.g., Holeckova et al., 2006; Sui et al., 2006; but see Laureys, Perrin, & Brédart, 2007). Yet, in most of these studies, the same self-referential stimulus was usually presented several times during the experimental session. After the results from Harris and Pasher (2004) and the present study, it seems that averaging across repeated trials is likely to fail giving rise to patients' responses that occurred after the first few presentations of self-referential materials.

In conclusion, present findings demonstrate that a unique and distinctive self-referential stimulus such as one's own face is not a potent distractor compared to other faces. The distraction it produces does not differ from that produced by another familiar face, is only temporary and is modulated by the position of the face within the participant's focus of attention. Future work should clarify whether this distraction is due to a difficulty to disengage attention as hypothesized here and/or whether the self-face has the capacity to automatically capture attention in some conditions.

Acknowledgments

This research was supported by a grant from the Belgian Fonds de la Recherche Fondamentale Collective (Grant n° 8.4506.05 – 2.4539.05) to SB. CD is Scientific Research Worker at the National Fund for Scientific Research (Belgium). We warmly thank Nathalie Jamaer for her help with preparation of participants' pictures and data collection. We thank Asher Cohen, Johan Wagemans and an anonymous reviewer for their constructive comments.

Chapter 7

DO PICTURES OF FACES, AND WHICH ONES, CAPTURE ATTENTION IN THE INATTENTIONAL BLINDNESS PARADIGM?

Christel Devue, Cédric Laloyaux, Dorothée Feyers, Jan Theeuwes, and Serge Brédart (Submitted).

Abstract

Faces and self-referential materials (e.g. the own name) are more likely to capture attention in the inattentional blindness (IB) paradigm than others stimuli. This effect is presumably due to the meaning of these stimuli rather than to their familiarity (Mack & Rock 1998). IB has mostly been investigated with schematic stimuli in previous work. In the present study, the generalisability of this finding was tested using photographic stimuli. In support to the view that faces constitute a special category of stimuli, it was found that pictures of faces resisted more to IB than pictures of common objects (Experiment 1) or than pictures of inverted faces (Experiment 2). In a third experiment, the influence of face familiarity and identity (i.e. the participant's own face, a colleague's face and an unknown face) on IB rates was evaluated. Unexpectedly, no differential resistance to blindness across these three kinds of faces was found. In conclusion, picture of faces attracted attention more than pictures of objects or inverted faces in the IB paradigm. However, this effect was not dependent on face familiarity or identity.

Introduction

From 1988 to the publication of their book in 1998, Mack and Rock carried out a research project aimed at investigating the relations between perception and attention (Mack & Rock, 1998). More specifically, they examined whether perception without attention was possible. To investigate this issue, they designed a paradigm in which an unexpected stimulus was presented in the visual field of an observer while his/her attention was focused on another task. In this paradigm, observers were instructed to report which arm (vertical or horizontal) of a large cross presented very briefly is longer than the other. This procedure was used during two or three trials (i.e. non-critical trials). Then, on the third or fourth trial (i.e. critical trial), a *critical stimulus* (CS) was unexpectedly presented simultaneously beside the large cross (see Figure 1). At this moment, observers were in conditions of *inattention* since they could not expect the appearance of the CS. Immediately after the length judgment task, observers were asked whether they had seen something besides the large cross that was not present before. Then, they were asked to describe it or to indicate it in a set of alternatives. After two or three non-critical trials, the CS was presented a second time. Therefore, observers were at that moment in a condition of *divided attention*, since they expected the appearance of something else. Finally, in the last trial in which the CS was presented, observers were instructed to ignore the length judgment task and to stare the fixation cross. This constituted a *control* trial in which full attention was devoted to the processing of the CS. This trial allowed the verification of the CS perceptibility.

In Mack and Rock's early experiments, critical stimuli consisted in simple geometrical shapes (e.g. a square, a diamond, a coloured spot). They found that a high rate of observers (up to 85%) failed to detect the CS, a phenomenon that they called *inattentional blindness* (IB, Mack & Rock, 1998). From these findings, Mack and Rock concluded that perception requires attention and that attention must first be captured before perception can occur. From this assumption emerged the question of whether certain important and meaningful stimuli would be particularly prone to capture attention.

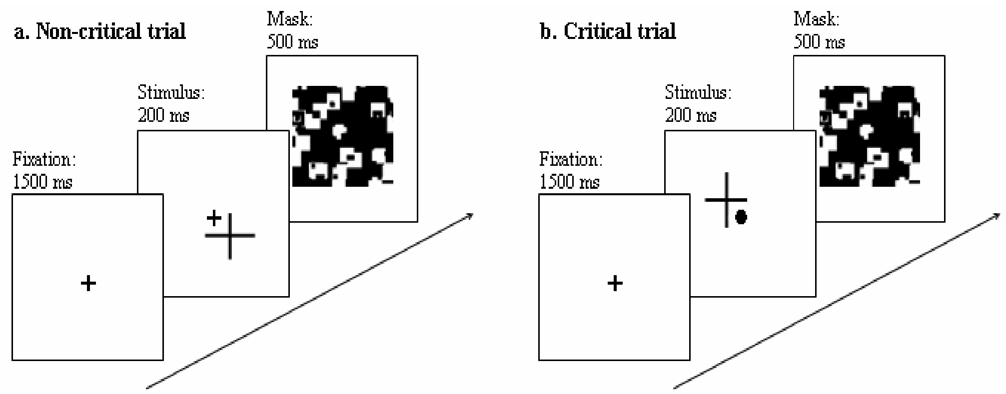

Figure 1. Presentation sequence of a non-critical trial (a) and critical trial (b): the critical stimulus (CS) appears at fixation besides the large cross (adapted from Mack & Rock, 1998).

Mack and Rock (1998) chose to address this question by presenting their participant's own name at fixation as CS in their IB paradigm. Indeed, since the late fifties, the own name has been described as particularly important with regard to its capacity to grab attention by comparison with other stimuli such as neutral words (Moray, 1959). Accordingly, Mack and Rock found that the own name was more resistant to IB than other stimuli (another name or some of the most frequent words in the English language such as "House" or "Time"). They then concluded that the own name captures attention because of its importance (rather than because of its lexicality or familiarity). Moreover, they carried out further experiments in which an alteration was made to the participant's name by replacing the first vowel by another one and found that the detection rates were then highly reduced. According to the authors, these results suggested that the own name does not capture attention because of its gross perceptual features (as an early selection of attention theory would have predicted, see Broadbent, 1958) since a modest alteration of these features had such a strong effect on its attention-grabbing capacity. Conversely, these results were in favour of a late selection theory (Deutsch & Deutsch, 1963) in which attention is assumed to be captured at a relatively 'late' stage of the visual processing at which the meaning of the stimulus is available.

In order to test whether other meaningful stimuli had the same capacity to capture attention, they conducted several additional experiments. Faces appeared to be ideal candidates as they seem to be special stimuli due to their great social importance (Bruce, 1988; Kanwisher et al., 1997; Perrett et al., 1985). They used cartoon-like faces and found that a happy face icon was more resistant to IB compared to other kinds of critical stimuli (sad, neutral, scrambled, or inverted happy faces as well as circles). Since they also found that the IB rates were significantly lower when the own name or the happy face icon were presented than when a highly frequent word such as ‘The’ was presented under comparable conditions, they concluded that familiarity alone cannot account for the detection of the own name or the happy face icon. More recently, Mack et al. (2002) confirmed the notion that one’s own name or a happy face icon capture attention because of their importance and high signal value using three different paradigms (IB, attentional blink, and stimulus crowding). Studies with patients also demonstrated the influence of such important stimuli on attention. For instance Vuilleumier and Schwartz (2001) showed that faces and emotional expressions can influence the distribution of spatial attention and that they can be processed despite lying on the unattended hemifield in brain-damaged patients presenting hemineglect. Recently, Perrin et al. (2006) using ERP showed that minimally conscious patients and some vegetative state patients present differential P3 component in response to their own name by comparison with other names.

Overall, these studies thus suggest that stimuli of great social importance such as faces and self-referential material such as one’s own name have the ability to capture attention. However, faces used in Mack and Rock (1998)’s experiments were cartoon-like happy faces and it is unknown whether the effects they reported would still hold if more realistic stimuli are presented. Other studies have used photographic stimuli in different paradigms and indicated that faces seem to be prioritised in terms of allocation of attention. For instance, David et al. (2006) used a change blindness paradigm and showed that, in natural scenes, gradual changes in facial expressions were better detected than gradual changes in objects’ colour. Ro et al. (2001) showed that, in a change detection task, changes to a single face presented among objects of different categories were better detected than changes to these objects. If they did not demonstrate that faces intrinsically capture attention, these studies nonetheless suggest that realistic pictures of faces are preferentially attended to than pictures of other objects. However, Palermo and Rhodes (2003) used the same paradigm as Ro et al. (2001) and found that changes to a single object presented among several faces were better detected than changes to faces, that is an “odd-one-out” effect, regardless of the significance of the stimuli. The extent to which faces are really able to capture attention thus remains unclear. More recently, Theeuwes and Van der Stigchel (2006) used the inhibition of return phenomenon to show that when a face and an object are simultaneously presented, the attention is automatically shifted towards the location of the face. Hence, this last study suggests that a realistic facial stimulus might also capture attention by comparison with another type of stimulus in the IB paradigm.

The first aim of this study was to assess the capacity of realistic representations of faces to capture attention in the IB paradigm. Therefore, in a first experiment we tested whether pictures of faces are more resistant to IB than pictures of other non-facial common objects (fruits and vegetables). In addition, in a second experiment, we compared the capacity of upright faces to capture attention with that of other stimuli matched for their low level properties (i.e. inverted faces).

The second aim of this study was to examine whether faces differing in their degree of familiarity and self-relevance may differ in their capacity to capture attention. Indeed, it is still unclear whether resistance to blindness is affected by the familiarity or identity of a face. In addition, there are controversies with regard to the capacity of self-referential stimuli to capture attention. Hence, we assessed whether a stimulus combining two properties likely to capture attention (i.e. the self-face is both a facial stimulus and self-relevant) is particularly prone to capture attention in the IB paradigm. The only study that, to our knowledge, investigated the role of familiarity on attentional properties with photographic stimuli is that of Buttle and Raymond (2003). In a change detection task involving highly familiar (famous) and recently learned faces, they showed that changes involving a famous face were better detected than changes involving a less familiar face. This study does not allow any prediction about the self-face but at least suggests that familiar faces could be better detected than unfamiliar ones.

Moreover, only few studies (Brédart et al., 2006; Devue & Brédart, in press; Laarni et al., 2000; Ninomiya et al., 1998; Tong & Nakayama, 1999) have investigated the attentional properties of the self-face. Indeed, previous studies investigating the attentional properties of self-referential materials used the own name rather than the own face (see e.g. Bundesen et al., 1997; Gronau et al., 2003; Harris et al., 2004; Harris & Pashler, 2004; Kawahara & Yamada, 2004; Mack et al., 2002; Mack & Rock, 1998; Wolford & Morrison, 1980). Yet the own face is more exclusively a self-referential stimulus than the own name. Indeed the former cannot be shared with other people whereas the latter can be. Moreover, control to these self-referential stimuli was sometimes inappropriate (i.e. neutral or unfamiliar stimuli were used).

In a third experiment, we thus assessed the attention-grabbing capacities of faces differing in their degree of familiarity in the IB paradigm. We compared the performance obtained when the self-face is presented to that obtained when a highly and personally familiar face (i.e. a colleague’s face) or an unknown face is shown. Thus, the comparison of the self-face with another highly familiar face would give the best possible approximation of the role of the self-referential component in attentional capture whereas the comparison with an unknown face would inform us on the effect of familiarity. In order to carry out such an experiment, we needed to present participants with pictures of themselves or a colleague whereas they did not expect to see such pictures. Due to these special conditions, the original paradigm designed by Mack and Rock (1998) was slightly modified. We inserted, between the inattention and the divided attention trials, a trial in which no CS was presented but which was nonetheless followed by an assessment of the detection and recognition of an additional item (*bias trial*). This way, we could determine whether participants were biased to think that they should see something just because the question was asked (i.e. false positives), and more importantly in the third experiment, that they were biased to see their own face. We also added this catch trial in the two first experiments in order to allow accurate comparisons between all three experiments.

EXPERIMENT 1

Method

Participants

Forty-eight participants (18 men) from the University of Liège took part in the experiment on voluntary basis. They were naïve as to the purpose of the experiment and had normal or corrected-to-normal vision. They gave their informed consent prior their inclusion in the experiment. As the crucial point in this paradigm is that a given participant can only be confronted once to one critical trial in condition of inattention, we used a between-subjects design. Thus, participants were randomly assigned to one of two experimental conditions: 'face' (n = 24) or 'object' (n = 24) as CS.

Stimuli

There were 8 possible CS: four oval-shaped objects (a lemon, a strawberry, a potato and a pear) and four unfamiliar faces (two males and two females). The size of these stimuli was about 0.9 degrees in width and 1.3 degrees in height (at a viewing distance of 56 cm and with a resolution of 0.035 cm per pixel). Each facial stimulus was obtained by cropping pictures between the hairline and the chin with the image manipulation software Gimp 2[7]. It was given an oval shape by tracing an ellipse in a rectangle of 25 X 35 pixels. Extraneous background information was concealed (see Figure 2a). The object stimuli were constructed using the same parameters as for faces (see Figure 2b). Contrast and luminance of each of these pictures were equalised by the experimenter. Each of the 4 objects and of the 4 faces was presented as CS to six different participants.

The arms of the cross that served as the stimulus for the length judgment task were black and had 4 different sizes comprised between 3.6 and 4.5 degrees (the two intermediate

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[7] www.gimp.org

sizes being equal to 3.9 and 4.1 degrees). The mask was a square of 8.9 degrees covering the area in which stimuli could appear. All these stimuli were presented on a mean grey background (see Figure 3).

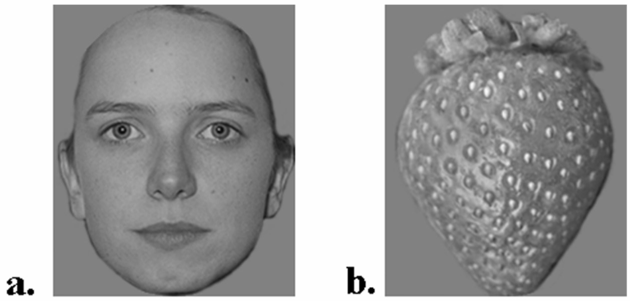

Figure 2. Examples of a facial stimulus (a) and of an object stimulus (b).

Procedure

Participants were tested individually in a dimly lighted room on a personal computer. They viewed stimuli at a distance of 56 cm controlled by means of a chin-rest. The stimuli were presented on a CRT 17 inches monitor with an 85 Hz refresh rate and the resolution of the screen was set to 1024 by 768 pixels. The presentation of the stimuli was controlled and responses were recorded with E-Prime 1.0 software[8]. Participants were instructed that they should perform a task on geometrical shapes. They were asked to stare at a centred fixation cross and to judge which arm of a larger cross presented very briefly was longer compared to the other one. Each trial was initiated by a key press of the participant when he/she was ready. A fixation cross was presented for 1500 ms. Then, a larger cross appeared for 200 ms randomly in one of the four quadrants on a 45° diagonal from the fixation, the arms intersection being at 2.3° from the fixation. The two arms of the cross were chosen randomly among the four possible sizes with the constraint that both of them could not have the same size. Participants indicated their decision with a key press (“b”= vertical or “n”= horizontal).

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[8] http://www.pstnet.com/products/e-prime/

During critical and control trials, a CS appeared at fixation (i.e. at the location of the fixation cross) for 200 ms at the same time as the larger cross. Finally a mask was presented for 500 ms.

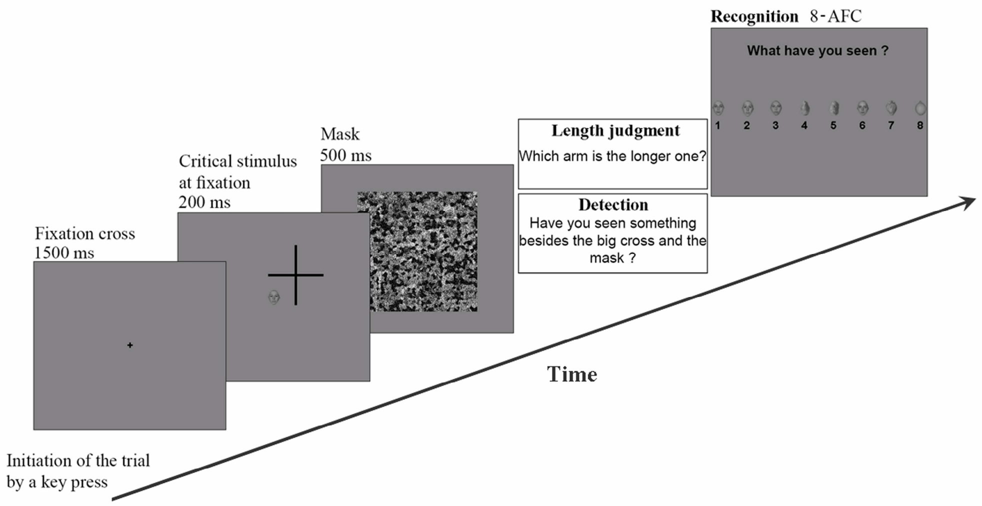

Figure 3. Time course of a critical trial in experiments 1, 2 and 3.

Each participant was presented with 9 trials (see Table 1). CS was presented during the fourth (*inattention trial*), the eighth (*divided attention trial*) and the ninth trial (*control trial*). The same CS was presented throughout the whole experiment to a given participant. After each critical trial, participants were asked if they had seen anything besides the large cross and the mask (referred to as the black and white spotted square) that was not present during previous trials. Regardless of their response, they had to choose what had just been presented among an 8-AFC composed of the four faces and the four objects. These eight items randomly appeared in one of eight possible locations (see Figure 3). In order to assess whether participants were prone to produce false positive, the CS was *not* presented during the sixth trial (*bias trial*). However, the participants were still questioned about the presence of something additional and they had to pick out what 'had been presented' in the 8-AFC. Before the ninth trial (*control trial*), participants were urged to concentrate on the centre of the screen and to stare at the fixation cross without paying attention anymore to the large cross. They were again asked if they had seen something additional and had to pick it out in the 8-AFC.

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9
Cross alone	Cross alone	Cross alone	Cross + Critical stimulus	Cross alone	Cross alone	Cross alone	Cross + Critical stimulus	To-be-ignored cross + Critical stimulus
			8-AFC		8-AFC		8-AFC	8-AFC
			Inattention		**Bias**		**Divided attention**	**Control**

Table 1. Illustration of the procedure used in experiments 1, 2 and 3.

Results

Since the present study was aimed at evaluating in the ability of faces or other stimuli to capture attention when they appear unexpectedly in condition of inattention, we focused our analyses on the inattention trial (i.e. first critical trial) for all analyses reported hereafter. Moreover, in the ‘detection rates’ section, we examined the tendency of participants to report the presence of an additional item whereas nothing has actually been presented by means of the bias trial.

Length judgment task

First, the performance on the primary task (i.e. line length judgement) was analysed. The overall accuracy on this task was 66%. A Chi-square analysis showed that the accuracy did not differ significantly between the two groups on the inattention trial, $\chi^2(1) = 2.42$, $p = 0.12$. Moreover, the rates of correct responses on critical trials (trials 4 and 8 being pooled), 68%, did not differ significantly from that on adjacent trials (trials 3, 5, 6 and 7 being pooled), 71%, $\chi^2(1) < 1$.

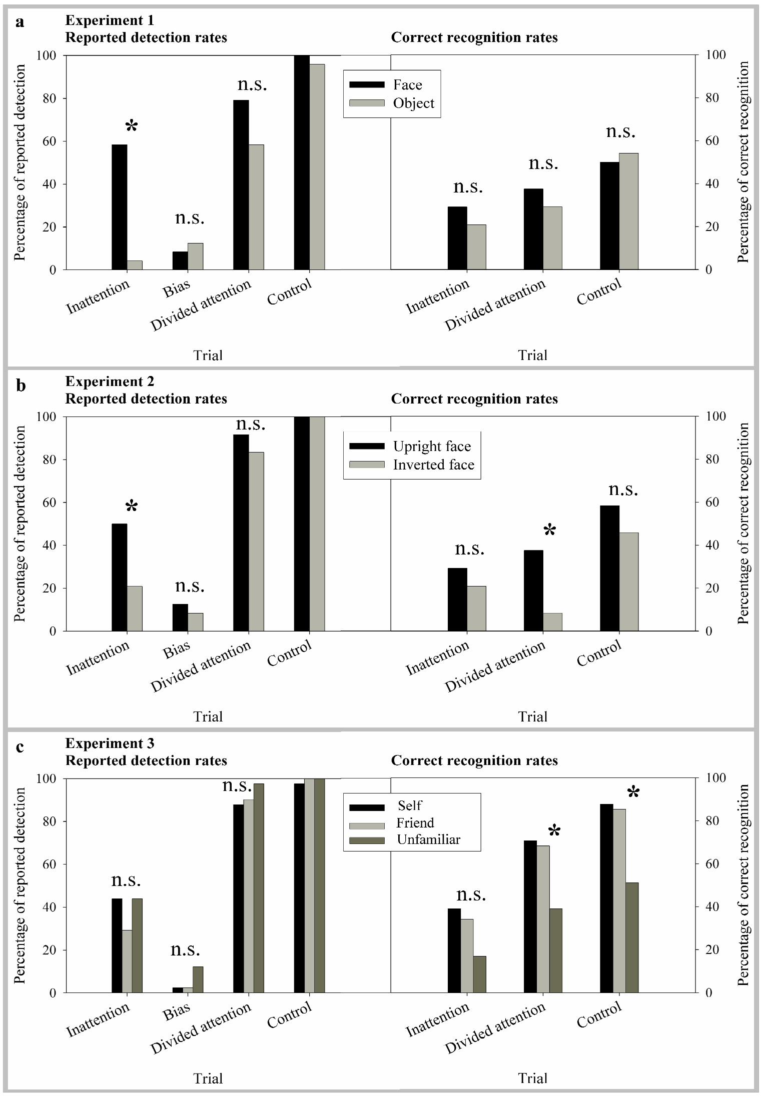

Figure 4. Left panels: Percentage of participants that reported having detected an additional stimulus as a function of the type of critical stimulus (CS) presented in critical and bias trials of experiments 1, 2 and 3. Right panels: Percentage of correct recognition of the CS among an 8-AFC. '*' refers to a significant *p* value below 0.05; 'n.s.' refers to a non-significant *p* value superior to 0.05. Note that we did not conduct analyses on the detection rates of the control trial because performance was at ceiling. This control trial indicates that the CSs were readily visible in condition of full attention.

Detection rates

We compared the detection rates as a function of the type of CS presented (i.e. face versus object) during the first critical trial by means of a Chi-square analysis. Faces (58%) were significantly better detected than objects (4%), $\chi^2(1) = 16.39$, $p < 0.001$. In addition, the bias trial indicated that only 2 participants from the 'face' condition (8%) and 3 from the 'object' condition (12.5%) reported seeing something whereas nothing had been presented. Complete results are presented on the left panel on Figure 4a for exhaustiveness.

Correct recognition rates

We compared the ability of participants to recognise the CS that has been presented on the inattention trial by means of another Chi-square analysis. The correct recognition rates did not differ significantly between faces (29%) and objects (21%), $\chi^2(1) < 1$. Complete results are presented on the right panel of Figure 4a.

Discussion

Current results confirm previous findings, now with realistic photographic stimuli, that faces are more resistant to IB than other objects (Mack & Rock, 1998). In general terms, this finding is consistent with the idea that faces are more likely to grab attention than other objects (Mack et al., 2002; see also Ro et al., 2001; Theeuwes & Van der Stigchel, 2006; but see Palermo & Rhodes, 2003). The present experiment that used realistic photographic stimuli also shows an overall IB effect of 69%. The present findings thus provide a confirmation of previous findings demonstrating the robustness of the IB effect (otherwise already demonstrated in more complex situations such as dynamic events, see Simons & Chabris, 1999).

Although faces were better detected than objects during the inattention trial, recognition rates did not differ significantly between faces and objects. This shows that despite the fact that they are not easily identifiable, faces possess the ability to capture attention more than another category of objects. This poor recognition performance is probably due to the difficulty to recognise a small novel face, presented unexpectedly while participants are engaged in another task, after a relatively short exposure (e.g. Bruce et al., 2001). Crucially though, even if participants were not capable of recognising a face in such conditions, this face nevertheless had a strong power to attract attention and reduce IB rates dramatically.

The bias trial also indicated that few participants (5 on 48, = 10.4%) were biased to report seeing something when nothing was actually presented. This suggests that those reporting seeing something on the first critical trial really did so since most participants were able to correctly report that nothing was presented[9].

It cannot be excluded that the results of Experiment 1 reflect some low-level differences between faces and other objects. For instance, because of their inner features, faces could be less homogenous than objects, rendering the former more readily detectable than the

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[9] However, one could argue that participants were not in the same situation during the inattention trial and during the bias trial in which attention was in fact already divided due to the earlier presentation of the first critical trial (we thank Ian Thornton for this suggestion). In order to answer this potential criticism, we recruited 18 new participants to whom the first critical trial (inattention) was not presented anymore. Thus, following three non-critical trials, the bias trial was presented and constituted the first trial after which participants were asked whether they had detected something additional although nothing had been presented. Results showed that 5 participants (28%) reported seeing something. When asked to describe what they had seen before the 8-AFC, not surprisingly, 3 participants were not able to answer and just had a feeling of having seen something, 1 described a picture composed of points appearing after the big cross and before the mask, and 1 described a strange large image with plants. These two descriptions clearly fit the appearance of the mask and indicate that some participants may confuse the perception of the mask with that of an additional item. These participants probably noticed the mask because of the question and confused it with something additional because they had not noticed it before. It is thus possible that the rates of false positives seemed higher when nothing was presented at first because participants did not know what there was to ‘see’ whereas when the bias trial was presented after a genuine critical trial people knew what could be presented and by consequence were surer that they had not seen such thing. This problem of false positives had already been addressed by Mack and Rock (1998). In a control experiment similar to that conducted here, they found that 25% of participants reported that there was something although nothing had been presented. Thus, according to Mack and Rock (1998), “to avoid appearing either dumb or blind, these subjects may have answered yes to our question even though they actually had not seen anything else” (p. 238). They concluded that the rate of IB is generally underestimated since these cases are actually additional cases of IB.

latter. To address this possibility, we conducted a second experiment in which we compared the detection of upright and inverted faces.

EXPERIMENT 2

The aim of this second experiment was thus to compare faces to another kind of CS that have exactly the same low level properties as faces (contrast, luminance, complexity, etc) but that is not perceived as a face, i.e. inverted faces. Indeed, it has been suggested that inverted faces are not processed as faces but rather as objects (e.g. Valentine, 1988). Hence, if a detection advantage for upright faces by comparison with inverted faces is obtained, it would confirm the view that the advantage is due to their meaning rather than to other lower level characteristics.

Method

Participants

We recruited 48 new participants (11 men) from the University of Liège. They were randomly assigned to one of two experimental conditions: 'upright face' (n = 24) or 'inverted face' (n = 24) as CS. They were naïve as to the purpose of the experiment and had normal or corrected-to-normal vision. They gave their informed consent prior their inclusion in the experiment.

Stimuli and procedure

The stimuli and the procedure were exactly the same as in Experiment 1 except that the four objects used in Experiment 1 were replaced by the four unfamiliar faces that had been flipped vertically. Each of these 8 CS was presented throughout the whole experiment to 6 different participants. The 8-AFC now comprised 4 upright faces and the same 4 inverted faces.

Results

Length judgment task

The overall accuracy on the length judgment task was 65 % which is similar to the 66% obtained in Experiment 1. Chi-square analyses showed that the accuracy did not differ significantly between the two groups on the inattention trial, $\chi^2(1) < 1$. Moreover, the rates of correct responses on critical trials (trials 4 and 8 being pooled), 59%, did not differ significantly from that on adjacent trials (trials 3, 5, 6 and 7 being pooled), 66%, $\chi^2(1) = 1.27$; $p = 0.26$.

Detection rates

As in Experiment 1 upright faces resisted more to IB than other stimuli. Indeed, upright faces (50%) were significantly better detected than inverted faces (21%),$\chi^2(1) = 4.46$, $p = 0.035$. Moreover, the bias trial indicated that only 3 participants from the ‘upright face’ condition (12.5%) and 2 from the ‘inverted face’ condition (8%) reported the presence of an additional item when nothing had actually been presented. Complete results are presented on the left panel of Figure 4b for exhaustiveness.

Recognition rates

The correct recognition rates did not differ significantly between upright faces (29%) and inverted faces (21%) after their first appearance, $\chi^2(1) < 1$. Complete results are presented on the right panel of Figure 4b.

Discussion

This second experiment confirms the findings of Experiment 1 that faces are more resistant to inattentional blindness than other stimuli. Here the stimuli of comparison were the same faces that were either upright or inverted. Since upright and inverted faces had exactly the same low level properties, this detection advantage for upright faces is thus imputable to their meaning. In the present experiment, the overall IB rates was 64.5% which is consistent with the IB effect found in Experiment 1 and again confirms the robustness of the IB effect. In line with Experiment 1, few participants (5 on 48, = 10.4%) reported seeing something when nothing was actually presented during the bias trial.

Finally, as in Experiment 1, upright faces benefited from a detection advantage without being better recognised than inverted faces after their first appearance.

In the preceding experiments we showed that an unfamiliar face grabs more attention than other stimuli. We will now examine whether familiarity and identity of a face influence its ability to capture attention.

EXPERIMENT 3

In this experiment, the resistance to blindness of three types of faces differing in identity and familiarity was compared. The CS was either an unfamiliar face (as in Experiment 1 and 2) or a familiar face. In that latter case, the CS was either the participant's own face or the face of a participant's friend.

Method

Participants

One hundred and forty-four participants (37 men) from the University of Liège participated in the experiment on a voluntary basis. Each of them had been photographed previously in the Cognitive Psychology Unit for their participation in a self and familiar face recognition experiment (each participant had taken part to these experiments with a friend/colleague and they were control of each other). They were recruited by phone (on average 11 months after they had been photographed) and were asked to participate in a visual perception experiment about geometrical shapes that appeared to be completely unrelated. Participants were randomly assigned to one of three experimental conditions: ‘self-face’ (n = 48), ‘colleague’s face’ (n = 49) and ‘unknown face’ (n = 47) as CS. They were naïve as to the purpose of the experiment and had normal or corrected-to-normal vision. They gave their informed consent prior their inclusion in the experiment.

Stimuli

Now, the CS was either a greyscale picture of a familiar or of an unfamiliar face. These facial stimuli were constructed using the same parameters as those described above. When the CS was unfamiliar (‘unknown face’ condition), it was chosen among a set of 6 unknown faces (3 males and 3 females). When the CS was a familiar face, it was either the participant’s own face (‘self-face’ condition) or the face of a participant’s friend (‘colleague’ condition).

Procedure

The procedure was exactly the same as in Experiment 1 and 2 except that the 8-AFC was now tailored for each participant. The 8-AFC was always composed of four faces of the same gender as the participant and of the same four objects as in Experiment 1. The four faces were two unknown faces and two familiar faces (the participant’s own face and his/her colleague’s face). Hence, whatever the group the participant belonged to, he/she had to choose between two familiar and two unfamiliar faces and could not make a default decision based on the face familiarity if he/she had not really recognised it. The four objects served as filler items in the 8-AFC and were never presented as CS during this experiment.

In addition, after the 9 trials, participants were presented with the four faces and were asked to identify them. To make sure that the possible differences obtained between the three groups of participants were due to the different familiarity of the CS they had been presented, participants who were not able to identify one (would it be their own face or their colleague’s face) or both familiar faces were discarded.

Results

Twenty-one participants could not identify at least one of the two familiar faces during the final identification phase (i.e. 7 participants in the 'self-face' condition, 8 in the 'colleague's face' condition and 6 in the 'unknown face' condition) and were discarded from further analyses (there were thus 41 participants per condition)[10].

Length judgment task

The overall accuracy on the length judgment task was equal to 69%, which is in line with the two previous experiments. Chi-square analyses showed that the accuracy did not differ significantly between the three conditions on the inattention trial, $\chi^2(2) = 2.36$, $p > 0.25$. Performance on critical trials (trials 4 and 8 being pooled), 70%, did not differ significantly from that on adjacent trials (trials 3, 5, 6 and 7 being pooled), 75%, $\chi^2(1) = 1.52$, $p = 0.22$.

Detection rates

Here we focused again on inattention trial to examine whether the self-relevance and familiarity of faces can influence their resistance to blindness. The null hypothesis that all three types of faces are equally resistant to blindness could not be rejected since the facial identity did not significantly influence the detection rates (self-face = 44%, colleague's face = 29%, unknown face = 44%), $\chi^2(2) = 2.46$, $p > 0.25$. However, to ensure that this numerical difference of 15% between the 'colleague's face' condition and the two other conditions did not reflect a genuine effect that the global Chi-square could not reveal, we perform two 2x2 analyses with the 'colleague's face' condition tested against the two other conditions. These two analyses did not reveal significant differences between the colleague's face condition and the other conditions, both $\chi^2(1) = 1.89$, $p = 0.17$.

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[10] Nonetheless, it has to be mentioned here that most of these 21 participants recognised the stimuli as being their own face and their colleague's face after we told them. Some of them admitted that they thought they had recognised the faces but did not dare to tell so. Some of them were also a bit stunned as they did not understand how the pictures of these faces could have ended up in the present experiment.

At the bias trial, only one participant in the 'self-face' condition (2.44%), one in the 'colleague's face' condition (2.44%) and five in the 'unknown face' condition (12.20%) reported seeing something when nothing additional was actually presented. Complete results are presented on the left panel of Figure 4c for exhaustiveness.

Correct recognition rates

A Chi-square analysis showed that the familiarity of the face tended to increase the recognition of the CS presented during the inattention trial (self-face = 39%, colleague's face = 34%, unknown face = 17%). However, the difference between the three groups was not significant, $\chi^2(2) = 5.18$, $0.10 > p > 0.05$. The right panel of Figure 4c nonetheless shows that this advantage of both familiar faces over the unknown face was significant in the divided attention and in the control trial.

Bias trial

We examined the participants' choices after the bias trial to evaluate whether they were biased to think that the experiment dealt with their own face and therefore that their own face had been presented. Overall (i.e. irrespective of participants reporting the presence of an additional item or not), 12 participants (9.76%) chose their own face when nothing had actually been presented: 2 (4.9%) from the 'self-face' condition, 7 (17.1%) from the 'colleague's face' condition and 3 (7.3%) from the 'unknown face' condition. In addition, binomial tests (confidence interval thresholded at $\alpha = 0.05$) were used to assess whether these rates differed from what had been expected by chance (i.e. 12.5%). Participants from the 'colleague's face' and 'unknown face' conditions chose their own face at random and participants from the 'self-face' condition chose their own face less often than expected by chance when nothing had been presented.

Among participants who reported having seen something on the bias trial (i.e. 7 participants, see above), none chose the self-face in the 'self-face' condition, one did so in the 'colleague's face' condition and none did it in the 'unknown face' condition.

Discussion

Unexpectedly, the results of this third experiment do not suggest any significant influence of self-relevance or of face familiarity on detection rates since all faces grabbed attention similarly. A first explanation for this null effect is that the combination of two properties likely to grab attention (i.e. facial aspect and self-relevance) does not increase the resistance of the self-face to blindness. Indeed, it seems that the detection rates reported when the self face was presented (i.e. 44%) was similar to those found for unfamiliar faces across our three experiments (i.e. 44% in the present experiment, 58% in Experiment 1, and 50% in Experiment 2, thus 51% on average).

However, our results indicated a non-significant numerical difference of 15% between the reported detection rates for a friend's face (i.e. 29%) and the two other types of faces (i.e. 44% for both). Therefore, an alternative explanation for this null effect might simply be a lack of statistical power. Indeed, IB experiments require a large number of subjects in order to reach good power and because participants were unexpectedly presented with their own face and a colleague's face, we were limited by the number of participants we could recruit. Nevertheless, given that the detection rate of the self-face was similar to that of unfamiliar faces, even if the difference between the colleague's face and other faces was significant, this would not mean that the self-face particularly attract attention but rather that the colleague's face is less prone to attract attention than another face.

Nonetheless, there are two points that suggest that the non-significant difference between the 'colleague's face' condition and the two other conditions does not reflect a genuine difference in the attention-grabbing capacity of such a highly familiar face. First, such a decrease in detection for the colleague's face in comparison with a less familiar face (the unknown face) is quite unexpected. We would rather have expected a linear effect where the attention-grabbing capacities decreased as the familiarity decreased (i.e. self-face > friend's face > unfamiliar face, see e.g. Buttle & Raymond, 2003). Second, because of this unexpected result, recognition data were analysed in more details. This analysis showed that the colleague's face, contrary to the others, was relatively well recognised when participants did not report that they had seen something additional after the first critical trial[11]. This could indicate that some participants who detected their colleague's face did not report it (e.g. because they did not remember that they had previously participated in an experiment in which they were paired with this particular person, found it 'weird' to perceive such a picture and were unsure of their perception) but nonetheless recognised it in the 8-AFC. This explanation is plausible if one imagines the situation of the participant. He/she, in most cases, is tested by an experimenter he/she does not know, on average 11 months after having been photographed to participate in another familiar faces experiment with his/her friend. Thus, it seems quite unlikely that this experimenter knows the identity of his/her friends and in addition have their pictures (see also footnote number 10)! In this situation, they had some reasons to be reluctant to report such a perception.

At the bias trial, like in the two other experiments[12], there were only few false positives since only 7 participants out of 123 (5.70%) reported seeing something when nothing was actually presented. The bias trial also allowed us to verify whether participants were biased to think that their own face had been presented due to their previous participation in a self-face experiment. Apparently it was not the case since participants were less than 10% to choose their own face when nothing was presented (i.e. after the bias trial). Moreover, after the bias trial, in all three conditions the choice of the self-face was not higher than random level and actually, in the 'self-face' condition, the choice of the own face was even lower than expected by chance.

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[11] In that situation, 28% of participants accurately recognised their colleague's face, against 17% that recognised their own face and 4% that recognised an unfamiliar face. The difference between the recognition of the colleague's face and an unknown face was significant, $\chi^2(1) = 4.84$, $p = 0.028$. Moreover, also in support of this idea, a binomial test indicated that the recognition of undetected CS was at random level for the self-face – Critical Interval = 3% to 28% - and for the unknown face - C.I. = 3% to 28% - but significantly higher than random level for the colleague's face - C.I. = 4% to 27%. In other words, although they reported that they did not detect the presence of an additional item, participants from the 'colleague's face' condition picked out their colleague's face in the 8-AFC more often than expected by chance.

[12] The reported detection rate in the present experiment was not significantly different from that obtained in Experiment 1, $\chi^2(1) = 1.18$, $p = 0.28$; or in Experiment 2, $\chi^2(1) = 1.18$, $p = 0.28$.

Finally, recognition rates indicated that familiar faces tended to be better recognised than unfamiliar faces even if the former were not more resistant to blindness than the latter (see Figure 4c).

General discussion

Previous studies using the IB paradigm have shown that some categories of important and meaningful stimuli such as faces or self-referential materials (e.g. the participant's own name) particularly capture attention and resist IB compared to stimuli of a lesser importance (Mack & Rock, 1998). The present study aimed at investigating the resistance of such important stimuli to inattentional blindness with realistic facial stimuli and to investigate further the role of familiarity and self-relevance in the IB phenomenon. We thus tested the attention-grabbing capacities of pictures of faces by comparison with pictures of common objects (fruits and vegetables, Experiment 1) or by comparison with pictures of inverted faces (Experiment 2). In addition, we compared three categories of faces in order to assess the influence of self-relevance and familiarity on attentional capture (Experiment 3).

Detection rates and resistance of facial stimuli to blindness

Our first experiment showed that faces were significantly better detected than other objects (i.e. 58% versus 4% of detection) under condition of inattention confirming with more realistic stimuli previous findings about the special attentional properties of faces (Mack & Rock, 1998; Ro et al., 2001; Theeuwes & Van der Stigchel, 2006; but see Palermo & Rhodes, 2003). In addition, results of our second experiment showed that upright faces were also better detected than inverted faces (i.e. 50% versus 20% of detection) ruling out any alternative explanation in terms of potential low level inherent differences between faces and objects. Finally, the result of the third experiment showed no significant difference between the detection rates of the self-face (44%), a colleague's face (29%) and an unknown face (44%). In addition, the self-face was clearly detected in the same range as the unknown face in Experiment 3 and also in the same range as unfamiliar faces in Experiment 1 and Experiment 2. This finding does not support the view that a stimulus combining two properties that are likely to grab attention such as the self-face can capture attention more than stimuli having only one of these two properties (i.e. facial aspect). We already addressed the issue of a potential lack of power in discussion of Experiment 3 and suggested that the non-significant decrease of reported detection rates for a friend's face might be due to some subjects being reluctant to report their perception. However, while there might be a power issue regarding a potential difference between the colleague's face and the other faces, there seems to be no power issue regarding the comparison between the own face (44%) and the unknown face (also 44% in Experiment 3). It remains that there are two possible interpretations regarding the similar detection rates for the self-face and unfamiliar faces:

(1) Self-referential stimuli have no special attentional properties. The first possibility is that self-relevance itself does not particularly capture attention in conditions of inattention (as shown in Experiment 3) and that a face is a sufficiently important and meaningful kind of stimulus to capture attention whatever its identity (by comparison with a non-face, as shown in Experiment 1 and Experiment 2). This would be in agreement with previous findings showing that self-referential stimuli are not special in the sense that they do not automatically capture attention (Bundesen et al., 1997; Gronau et al., 2003; Harris et al., 2004; Harris & Pashler, 2004; Kawahara & Yamada, 2004; Laarni et al., 2000). The conditions in which self-referential stimuli have been shown to elicit attentional bias by comparison with other stimuli were as follow: when they were presented as distractor but that they were related with the ongoing task (Brédart et al., 2006; Gronau et al., 2003; Kawahara & Yamada, 2004), when - if unrelated with the ongoing task - they were presented centrally (i.e. within the observer's focus of attention, sees Gronau et al., 2003) and when enough attentional resources were available for their processing (Harris & Pashler, 2004). By contrast, self-referential stimuli did not particularly grab attention when they were presented peripherally (i.e. outside the observer's focus of attention) and that their presentation was unrelated with the ongoing task (Gronau et al., 2003; Kawahara & Yamada, 2004; Laarni et al., 2000) or when attentional capacities were exhausted by another task preventing their processing (Harris & Pashler, 2004). Therefore, the current study indicates another specific condition in which self-referential stimuli might not be particularly prone to capture attention: when they are presented at the centre of the visual

field, unexpectedly and briefly while observers are engaged in another unrelated and demanding task.

(2) Need of attention to process identity. The second interpretation of our results could be that attentional capture is indeed determined by meaning and significance (see Mack & Rock, 1998), but by a 'rough' meaning, at a processing stage where precise semantic details and fine sub-categorisation are not available yet (i.e. a 'not that late' selection of attention, see e.g. Lachter et al., 2004 for a similar view). In order for faces to capture attention outside our direct attentional focus, it is required that there are perceptual processes that automatically scan and analyse the visual field for face stimuli. Because faces capture attention one has to assume that faces are discriminated by some 'preattentive' or unconscious processing (Theeuwes & Van der Stigchel, 2006). The current findings suggest that the discrimination between a face and a non-face configuration can be based on this early preattentive processing (that could take place in the occipito-temporal cortex, see Devue et al., 2007). However, in order to discern the identity of the face, a second 'attentive' processing stage (possibly originating in the fusiform gyrus, see Devue et al., 2007) may be necessary. This could explain why faces are more likely to capture attention than common objects (see Experiment 1) or to unusual facial configuration (i.e. inverted face, Experiment 2) while faces of different identities and levels of familiarity do not differ in their attention-grabbing capabilities (see Experiment 3). It would be interesting to address further the generalisability of our finding to other types of facial classification (e.g. gender, gaze direction, race, or emotional expression). For instance, one could ask whether pictures of faces differing in their emotional facial expressions could be differentiated pre-attentively. Indeed, this topic is also highly debated in the literature (for a review, see e.g. Weierich et al., in press). A first answer has been brought by Mack and Rock (1998) that showed that happy-face icons were more readily detected than neutral or sad schematic faces. However, it is probable that Mack and Rock' participants encountered happy-face icons far more often than their sad or neutral counterpart (e.g. in the eighties, the yellow smiley face was a famous symbol of 'house' music). Therefore, it is uncertain whether this effect did not actually reflect a mere familiarity effect. Using photographic emotional facial stimuli would thus allow an answer to that question. If faces displaying different facial emotions could

differentially resist to blindness in the IB paradigm, it would be an indication that emotional information, contrary to identity information, can be processed pre-attentively.

In sum, further work is necessary to determine the reason of our null effect (i.e. a non-specificity of self-referential stimuli in the IB paradigm or the need of attention to process identity). If our null effect reflects a genuine absence of difference in the capacity of different faces to resist to blindness, then why did some other studies find that self-referential stimuli *capture* or *attract* attention (e.g. Brédart et al., 2006, Mack et al., 2002, Mack & Rock, 1998, Moray, 1959, Shapiro et al., 1997, Wolford & Morrison, 1980)? We propose a '*retention hypothesis*' to explain the discrepancy between present results and previous ones. It seems that terms such as attentional 'capture', 'attraction' or 'draw' might have been used inadequately. It has to be mentioned here that 'self-effects' found previously were either reflected by an increase or by a decrease in performance due to the presentation of self-referential stimuli. Indeed, some studies showed that self-referential stimuli were advantaged (e.g. enhanced reportability) by comparison with other stimuli and concluded that they attract attention (e.g. Shapiro et al., 1997, Wolford & Morrison, 1980). However, in those cases, this advantage may be due to the fact that self-referential stimuli are processed more efficiently than less familiar stimuli once they are already located in the observer's focus of attention rather than to a capture of attention (see e.g. Bundesen et al., 1997). This is what our recognition data suggests: once a face has attracted attention (because of its facial properties per se and independently of its familiarity) and that this face happens to be a familiar face, then it will be processed more efficiently and therefore better recognised than a novel face.

By contrast, in other studies, self referential-stimuli produced an interference effect (i.e. an increase of reaction times or of error rates, see e.g. Devue & Brédart, in press; Harris & Pashler, 2004; Wolford & Morrison, 1980). We argue that this interference is not necessarily due to a capture of attention by this stimulus. Rather, it could be due to a difficulty to disengage attention from this stimulus once it is attended by the observer. In other words, it is possible that even though the self-face may not *capture* attention relative to other faces, the self-face nonetheless *retains* attention more than other faces once the attention is focused on it (see Fox et al., 2001 for a similar claim with fear-related stimuli). A recent eye-movement study (Devue et al., submitted) supports this assumption. In that study, participants were to look for a specific facial configuration independent of identity on a 6-faces display. On some trials, the self-face or another familiar face (i.e. a friend's face) was presented irrelevantly with the ongoing task among 5 unfamiliar faces. We found that the participant's eyes did not go faster to the self-face (or to the friend's face) than to an unfamiliar face (i.e. the two familiar faces did not attract attention automatically). However, once the self-face was within the participant's focus of attention (i.e. when it was overtly attended), it was fixated longer than unfamiliar faces, suggesting that familiar faces may just benefit from a preferential allocation of attention.

In conclusion, this retention hypothesis could explain some apparent discrepancies in the literature about self-referential stimuli. It is possible that studies that found a "self effect" used a paradigm involving a capture as well as a retention of attention (e.g. if the self-referential stimulus is located within the observer's focus of attention, see Devue & Brédart in press; Shapiro et al., 1997; Wolford & Morrison, 1980; or if the task demands allow attentional shifts towards self-referential stimuli located peripherally, see Brédart et al., 2006) and that this effect was actually due to the retention and not to the capture of attention. By contrast, studies that did not find specific 'self-effect' could have used paradigms involving only a capture of attention (e.g. if the self-referential stimulus is located outside the focus of attention and that its presentation is irrelevant for the task at hand, see Laarni et al., 2000).

Recognition rates

In our two first experiments faces were not better recognised than common objects (Experiment 1) or that inverted faces (Experiment 2) despite that faces were more readily detected than other stimuli. This is in line with our hypothesis formulated above that the visual system can detect facial structures pre-attentively but that further processing is necessary to access other information such as identity. Recognising a novel face after a so short exposure seems quite difficult (e.g. Bruce et al., 2001).

In Experiment 3, familiarity affected recognition performance even though all three faces similarly attracted attention. Indeed, overall familiar faces were better recognised than unknown faces (at least after several presentation of the CS). These recognition results are consistent with the two hypotheses formulated above as regard with our detection results (i.e. self-face not special per se or need of attention to process identity). Indeed, the recognition performance suggest that once the attention is on a face, the processing of the self-face or another highly familiar face is facilitated by comparison with that of a face met for the first time. This advantage in terms of recognition for familiar faces has been shown previously (see for instance Bruce et al., 2001) and is probably due to the fact that the robust representation built after an extensive experience with highly familiar persons' faces facilitates their processing (Tong & Nakayama, 1999).

False positives and participants' bias

In our three experiments, the bias trial (i.e. the trial without CS inserted between the inattention trial and the divided attention trial) showed that false positives were quite unlikely (i.e. less than 10% in all experiments). This indicates that participants who reported the presence of the CS after the inattention trial did so accurately since they were able to correctly judge that nothing had been presented in the bias trial that followed.

Because it was presented after the inattention trial, the bias trial did not constitute a perfect measure of the occurrences of false positives. However, it was impossible to check the occurrence of false positives before the first critical inattention trial since by definition in this paradigm an observer can only be once in condition of inattention. Nonetheless, in the specific context of our third experiment this trial constituted a source of information about the reliability of participants' verbal reports. Indeed the bias trial allowed us to control that participants were not biased to think that the experiment dealt with their own face. Results indicated that participants did not tend to infer that their own face had been presented and that the responses they gave on the other trials are quite trustworthy.

Conclusion

To summarise, our results showed that pictures of unknown faces were better detected than pictures of common objects or inverted faces. A last experiment showed that the self-face or another highly familiar face do not particularly capture attention as all three faces were similarly resistant to IB. However, once a familiar face has been attended, its processing is facilitated by comparison with that of a novel face. This study gives rise to novel hypotheses to investigate. The first possibility is that self-referential materials have no special attention-grabbing capacities, at least in the conditions defined by the IB paradigm. The second possibility is that the access to the precise meaning and a fine sub-categorisation of a facial stimulus are not yet possible at the moment the attention is captured and that attention is necessary to process identity.

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Chapter 8

YOU DO NOT FIND YOUR OWN FACE FASTER; YOU JUST LOOK AT IT LONGER

Christel Devue, Stefan Van der Stigchel, Serge Brédart, and Jan Theeuwes (Submitted).

Abstract

Previous studies investigating the ability of high priority stimuli to grab attention reached contradictory outcomes. This study used eye tracking to examine the effect of the presence of the self-face presented among other faces in a visual search task in which the face identity was task-irrelevant. We assessed whether the self-face (1) received prioritized selection (2) caused a difficulty to disengage attention, and (3) whether its status as target or distractor had a differential effect. We included another highly familiar face to control whether possible effects were self-face specific or could be explained by high familiarity. We found that the self-face interfered with the search task. This was not due to a prioritized processing but rather to a difficulty to disengage attention. Crucially, this effect seemed due to self-face familiarity, as similar results were obtained with the other familiar face, and was modulated by the status of the face since it was stronger for targets than for distractors.

Introduction

When we open our eyes, we receive a large amount of visual information. Because our visual system has a limited capacity, selection must occur to prioritize important stimuli while ignoring less important ones. For almost fifty years, debates have opposed partisans of an early selection of attention (Broadbent, 1958), to whom this attentional selection concerns the gross stimulus features at an early stage of processing, to partisans of a late selection of attention (Deutsch & Deutsch, 1963), to whom the attentional selection takes place after semantic processing of all the incoming information. To resolve these debates highly important stimuli (e.g., one's own name) have been used, trying to determine whether they can be processed in conditions where they are supposedly unattended. These studies led to contradictory outcomes.

The infatuation for self-referential stimuli has started after that Moray (1959) showed that participants better remembered that they had heard their own name presented to one ear compared to other words while repeating aloud a message presented to the other ear. In a visual tantamount of Moray's paradigm in which participants were instructed to make a parity judgment on two digits flanking a to-be-ignored word (that was their own name on some trials), 80% of participants reported that they had seen their own name whereas they recognized only 68% of words presented in similar conditions (Wolford and Morrison, 1980). Moreover, the own name is particularly resistant to the attentional blink (Shapiro, Caldwell, & Sorensen, 1997) and to repetition blindness (Arnell, Shapiro, & Sorensen, 1999) during rapid serial visual presentations when compared to other names or nouns. In the inattentional blindness paradigm, the own name is also less subject to blindness than other names or frequent words (Mack & Rock, 1998). Additionally, Mack and Rock (1998) showed that the own name pops out of a display of up to 12 items in a visual search task (but see Harris, Pashler, & Coburn, 2004 who obtained search slopes not flat enough to claim that the own name pops out even if it was detected more rapidly than other names).

However, Bundesen, Kyllingsbaek, Houmann, and Jensen (1997) showed that one's own name does not automatically attract attention. In their experiment two white-coloured (to-be-ignored distractors) and two red-coloured (to-be-reported targets) names were presented. The own name was presented on some trials as target or as distractor. The own name presented as distractor did not cause more interference than other names but participants were more accurate in reporting their own name presented as targets than in reporting targets from display without their own name. However, a control experiment showed that this advantage for the own name presented as target was not attentional, but rather reflected a better identification of the participant's own name compared with other names. Other studies later demonstrated that one's own name summons attention when participants are set to identify target names but not when participants are set to find the colour of a target (Kawahara & Yamada, 2004). Similarly, in a Stroop-like task, the own name attracted attention if presented centrally within the participant's attentional focus but when presented peripherally, it attracted attention only when it was task-relevant but not when it was task-irrelevant (Gronau, Cohen, & Ben-Shakhar, 2003).

More recent studies have examined the attentional properties of another self-referential stimulus, the self-face, and also found contrasting results. For instance, Laarni et al. (2000) found that only 18% of participants reported the presence of their own face in the background while they were performing a matching task on two faces presented at foreground. Similar results were obtained with a celebrity face (the Finnish President). Conversely, Brédart, Delchambre and Laureys (2006) found that the self-face flanking a classmate's name in a face-name interference paradigm produced a stronger interference on the processing of this name than in the reverse situation when a classmate's face flanked the participant's own name. This suggests that the self-face also has some attention-grabbing capacity. Accordingly, Tong and Nakayama (1999) showed that the self-face was more quickly detected among distractors than strangers' faces, even when presented in atypical orientations and after hundreds of trials.

In the present study, we used the eye tracking technique to investigate more precisely the way in which attention is allocated when the self-face is presented among unfamiliar faces. We put three main questions: (1) Do our eyes go faster to the self-face than another face? In other words, is the self face prioritized in visual search? ; (2) Once attending a face, do our eyes stay longer on the self-face than on another face? In other words, does the self-face hold attention?; (3) Are these potential effects dependent on the status of the self-face as target or distractor? In order to disentangle “self-effect” from familiarity effect, we included another highly familiar face (a friend’s face) in the experiment. We designed a visual search task in which participants searched an array of familiar and unfamiliar faces looking for a face with a particular configuration resulting from the pronunciation of a specific sound. The task implied processing facial features but without the need to process the facial identity. Therefore, the familiarity and identity of the faces were completely task-irrelevant. Moreover, the task-relevant features were neutral with respect to emotional content in order to prevent any effect of other confounding emotional variables.

Method

Participants

Twenty-two observers (four males) were recruited by gender-matched pairs so that each of them served as the friend for the other participant.

Stimuli

Twenty-two individuals (11 females and 11 males) had been photographed to be used as unfamiliar faces, in a frontal position while pronouncing a [m] and an [o] (i.e., two easily producible and differentiated phonemes, see Figure 1). Each participant in the experiment was also photographed in similar conditions, the two pictures being used as “self-face” for him/herself and as “friend’s face” for his/her friend. All pictures were converted in greyscales. Hair below the ear lobes and neck were removed so that all faces had an overall oval shape. Faces were placed on a uniformed light grey background and resized to subtend 2.9 degrees in height and around 2.1 degrees in width. The self-face was presented in a mirror orientation.

Figure 1. Sample face stimuli showing a [m] sound (top) and an [o] sound (bottom).

Procedure

Participants were individually tested in a dim-lighted room. They were maintained at a 75 cm distance from the computer screen by means of a chinrest. Eye movements were measured with an Eye Link II eye tracking system with 500 Hz sampling rate. Participants were instructed to judge whether a target face was present or absent in a 6-faces display (see Figure 2) by means of two response keys. For half of the participants the target face displayed a [m] and remaining distractors displayed an [o]. The reversed situation was presented to the remaining half of participants. Participants received no instruction about the presence of familiar faces. Each trial began with a fixation cross that participants were instructed to stare at until the presentation of the faces. After 500 ms, 6 faces positioned on a virtual circle at 8.3 degrees around fixation appeared until a response was made (up to 3 seconds), followed by a blank of 1000 ms. If participants moved their eyes away from fixation (1.3 degrees) before the pictures onset, they heard a “beep” sound. They received a visual feedback in case of an incorrect or too slow response.

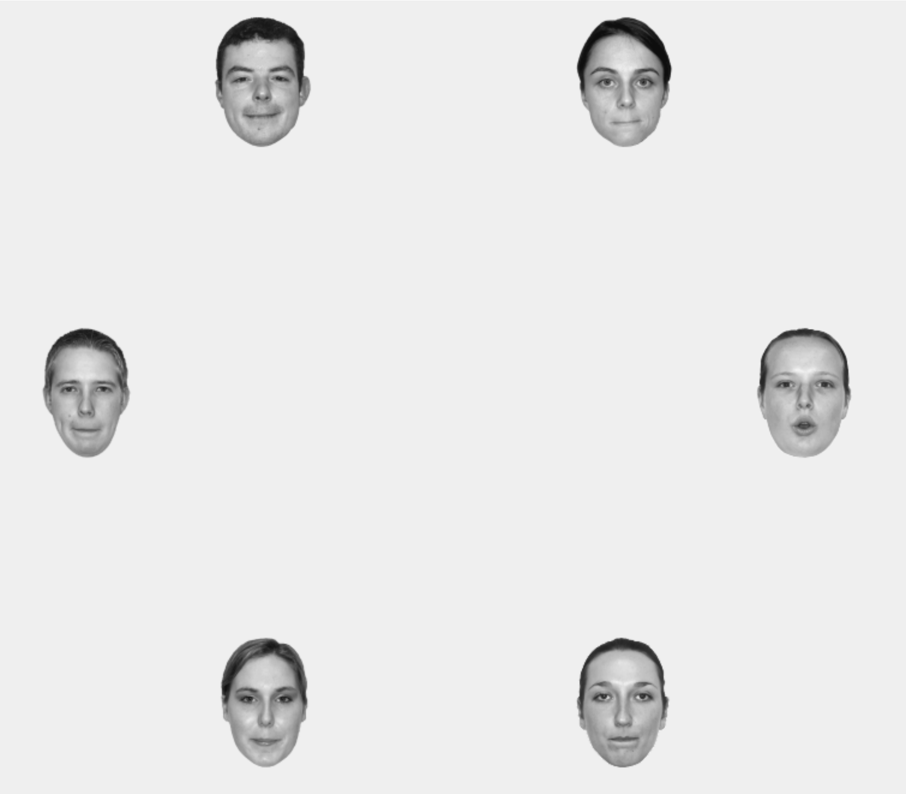

Figure 2. Illustration of a 6-faces display in which a target is present ([o] target among [m] distractors).

The test included 288 trials presented in a random order. A target was present in 50% of these trials. Each familiar face was presented a total of 72 times (the self-face on 25% of trials and the friend’s face on 25% of trials) distributed as follow: one half of the cases in the absent target condition (36 times) and the other half of the cases in the present target condition (36 times). In that latter case, each familiar face was the target 1 time out of 6 (6 times) and it was a distractor the 5 remaining times out of 6 (30 times). Each familiar face was always presented along with 5 unfamiliar faces. Hence, the processing of the familiar faces was completely irrelevant for the task and the presence of one of these faces was totally unpredictive of the correct response.

Displays were only composed of unfamiliar faces in the remaining 50% of trials that were distributed as follow: 72 trials with a target present and 72 trials with no target. The unfamiliar faces were picked up randomly among the set of 22 unfamiliar faces with the constraint that two identical faces could not appear within the same trial[13,14].

Before the test, participants performed a 48-trials training session composed of 6 additional unfamiliar faces that were not presented during the test.

Design and data analysis

We first examined the effect of the Condition (target present vs. target absent) and of the inclusion of a familiar face within the display (Display type: self-face, friend's face, all unfamiliar faces) on mean reaction times (RTs) and on mean number of saccades. The *mean number of saccades* was the number of eye movements necessary to judge correctly whether the target was present or absent (from the display onset until a correct response was given). These analyses determined whether the presence of a familiar face within the display interfered with the ongoing task by comparing it to a condition in which only unfamiliar faces were presented.

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[13] Each individual unfamiliar face had the same probability to be presented as each familiar face (in 25% of trials) and the same probability to be presented as a target (2.1%) or as a distractor (22.9%).

[14] To ensure that acuity from fixation was sufficient to recognize the faces at this eccentricity we conducted a control experiment with 8 other observers. The design was the same as in the main experiment except that one single face was presented at one of the 6 possible locations. The five other locations were occupied by grey ovals. The presentation time was reduced to 180 ms to prevent participants from making effective saccade and fixating the face. The faces were either the participant's face, one familiar face or 2 unfamiliar faces (displaying an "M" in a half of the trials and an "O" in the other half). Each person's face appeared in 25% of trials. Participants were to perform a 3-AFC (i.e. "me", "friend" or "unfamiliar face") identification task. The correct identification rates were 94%, 95% and 96%, respectively, indicating that faces were readily recognizable at this eccentricity.

In addition we assessed, for target faces, the effect of the Face's identity (self-face, friend's face, unfamiliar face[15]) on the first time to arrive at this very face. The *first time to arrive at the target* corresponded to the delay between the display onset and the time point where the eyes landed for the first time on the relevant face. This analysis assessed the existence of a prioritization of processing for the self-face. Finally, we examined the effect of the Face's identity and of its Status (target vs. distractor[16]) on *total glance duration*; a measure defined as the total time spent fixating the face. This analysis tested whether the self-face holds attention more than another face. In order to properly compare targets and distractors, only target present trials were taken into account in this analysis. Moreover, only trials in which a correct response was given and in which the relevant face was fixated were included in these two analyses.

Trials with anticipatory eye movements (latencies under 80 ms) were excluded from analyses.

Results

Data of two participants that only had respectively 20% and 23% of analysable data (e.g., trials without too early saccades or errors) and data of one participant whose response time and accuracy was more than 2.5 SD by comparison with the mean of the sample was discarded.

RTs. A two-way repeated measures ANOVA with Condition (target present vs. absent) and Display type (i.e., the face included in the display: self-face, friend's face, all unfamiliar faces) as factors was conducted on RTs. Condition had a significant effect, $F(1,18) = 386.34$; $p < 0.001$, with faster responses when the target was present ($M = 1373$ ms, $SD = 254$ ms) than when the target was absent ($M = 1878$ ms, $SD = 370$ ms). Display type also

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[15] The unfamiliar face identity represents "pure" unfamiliar trials in which no familiar face was present in the display.

[16] The unfamiliar distractor condition was computed by choosing one unfamiliar face at random among the possible unfamiliar distractors.

had a significant effect, *F*(2,36) = 3.63; *p* < 0.05. Planned comparisons indicated that RTs were slower when the self-face (*M* = 1642 ms, *SD* = 276 ms) and when the friend's face (*M* = 1630 ms, *SD* = 252 ms) were presented than when only unfamiliar faces (*M* = 1604 ms, *SD* = 226 ms) were presented, *p* = 0.018 and *p* = 0.049. By contrast, RTs were not significantly different when the self-face and when the friend's face were presented, *p* = 0.47. There was no interaction between Condition and Display type, *F* < 1 (see Figure 3A).

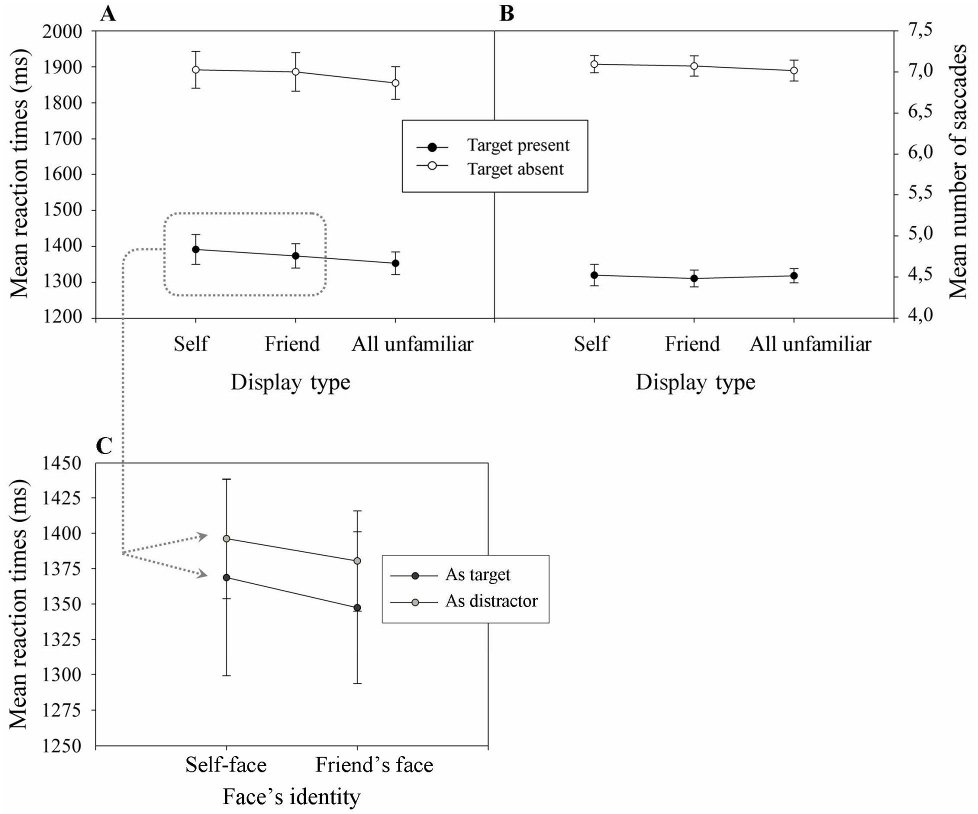

Figure 3. Mean reaction times (A) and mean number of saccades necessary to judge whether the target is present or absent (B) as a function of the Condition and of the face contained in the display (Display type). Mean reaction times (C) in the target present condition as a function of the Status (target vs. distractor) of the familiar faces present within the display. Error bars represent SEM.

Moreover, to decompose the interference caused by the familiar faces as a function of their status in the target present condition, we conducted a two-way repeated measures ANOVA with Status (target vs. distractor) and Face's identity (self-face vs. friend's face) as factors. There was no significant effect nor interaction, all Fs < 1 (see Figure 3C).

Mean number of saccades. We also conducted a 2 Condition by 3 Display type ANOVA on mean number of saccades. Condition had a significant effect, $F(1,18) = 573.56$; $p < 0.001$, as less saccades were necessary to respond when the target was present ($M = 4.51$, $SD = 0.69$) than when the target was absent ($M = 7.06$, $SD = 0.84$). Display type had no significant effect, $F < 1$, and there was no interaction, $F < 1$ (see Figure 3B).

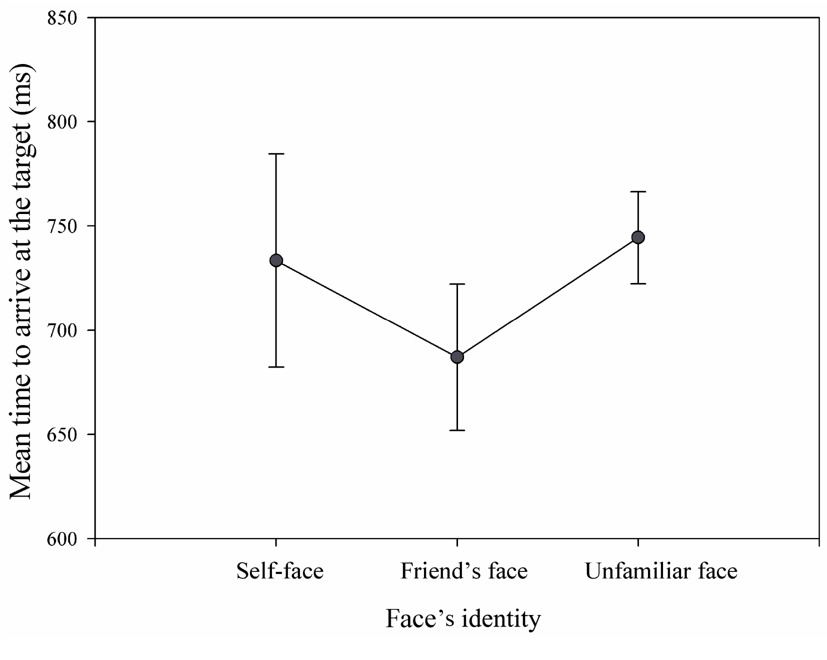

Figure 4. Mean time to arrive at a target face as a function of its Identity. Error bars represent SEM.

First time to arrive at the target. In this analysis we determined the first time participants arrived with their eyes at the self-face, a friend's face or an unfamiliar face (Face's identity) as targets. A one-way repeated measures ANOVA showed no effect of Face's identity, *F* < 1 (see Figure 4).

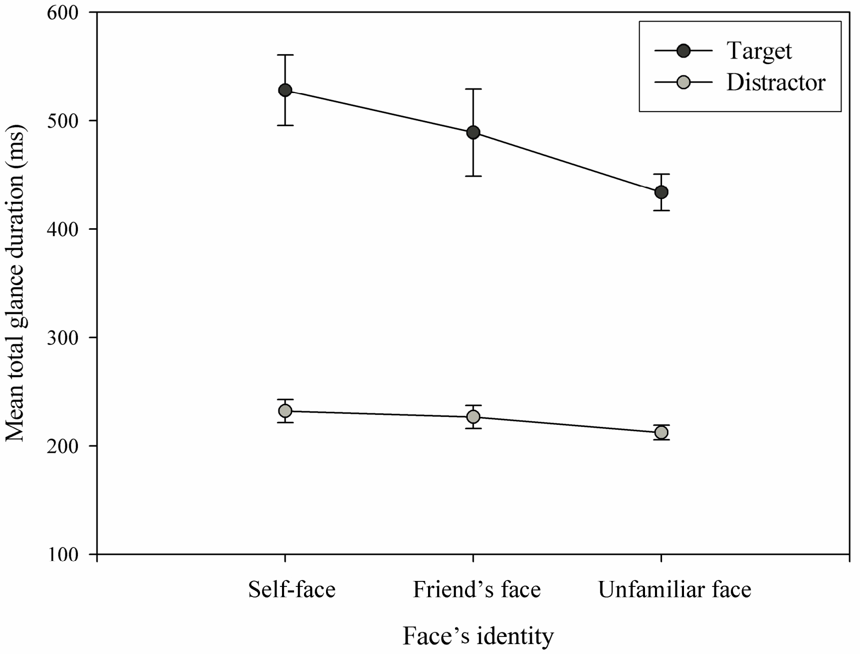

Figure 5. Mean total glance duration on a face as a function of its Status (target vs. distractor) and Identity. Error bars represent SEM.

Total glance duration. A two-way repeated measures ANOVA was performed to determine whether there was a difference in glancing at the self-face, a friend's face and an unfamiliar face (Face's identity) depending on whether it was a target or a distractor (Status). Face's identity affected the total glance duration, $F(2,36) = 7.74$; $p < 0.002$. Planned comparisons indicated that the self-face ($M = 380$ ms, $SD = 121$ ms) and the friend's face ($M = 358$ ms, $SD = 148$ ms) were fixated longer than an unfamiliar face ($M = 323$ ms, $SD = 67$ ms), $p < 0.001$ and $p < 0.05$, respectively, the two familiar faces not differing between each other, $p = 0.14$. Status of the face significantly influenced the total glance duration, $F(1,18) = 146.46$; $p < 0.001$, with target faces ($M = 484$ ms, $SD = 207$ ms) being fixated longer than distractor faces ($M = 224$ ms, $SD = 58$ ms).

The interaction between Face's identity and Status was significant, $F(2,36) = 3.64$; $p < 0.05$. Planned comparisons indicated that the self-face as target was fixated longer than unfamiliar target faces, $p < 0.001$, and that the friend's face as target only tended to be fixated longer than unfamiliar target faces, $p = 0.072$. The two familiar faces as targets were not differentially glanced, $p = 0.17$. The self-face as distractor was also fixated longer than an unfamiliar distractor face, $p < 0.02$. The other comparisons between identities did not reach significance, all *p*s > 0.10. All faces were fixated longer when they were targets than when they were distractors, all *p*s < 0.001 (see Figure 5).

Discussion

The first finding is that search in our task was performed in a slow and serial manner (see Figure 3A and B; a movie showing a sample of eye movements is also presented as supplementary material). Importantly and consistently with previous observations (Brédart et al., 2006), the presence of the self-face in the display interfered with the ongoing task as observers responded faster to displays in which only unfamiliar faces were presented compared to displays in which the self-face was present. This effect is even more striking that even if the processing of faces was necessary to the task, the face identity was completely task-irrelevant. Critically, the presentation of another familiar face also caused a distraction arguing in favor of a familiarity effect rather than a "self effect".

Crucially, the current data allow us to directly determine whether the self-face automatically summons attention in comparison to an unfamiliar face. We assessed the delay between the onset of the display and the moment a saccade landed for the first time on a face. We found no effect of the face's identity as the time to arrive on a face was similar for all three types of faces. Note however that our control study clearly indicates that the faces were readily recognizable from the central fixation point. In other words, the absence of attentional prioritization cannot be due to insufficient perceptual acuity when fixating the middle. Inconsistently with conclusions drawn from previous studies with the own name (Mack & Rock, 1998; Wolford & Morrison, 1980), current results thus clearly indicate that the self-face does not benefit of attentional prioritization and does not pop out of a display composed of other faces. However, this result is consistent with previous studies showing that the own name (Bundesen et al., 1997; Harris et al., 2004) or the self-face (Laarni et al., 2000) does not summon attention. These discrepancies between previous findings could be explained by a retention component.

Indeed, our eye movement data also permit to directly assess whether the self-face holds attention in comparison with another face. We found that fixations lasted longer on the self-face and on the friend's face in comparison with unfamiliar faces. Therefore, even if familiar faces are not prioritized in visual search, they are fixated longer once they are in the focus of attention and it is more difficult to disengage attention from those familiar faces by comparison with less familiar faces. Hence, highly familiar stimuli could just benefit from a preferential allocation of attention instead of a genuine ability to capture attention.

Present findings could thus resolve apparent contradictions in previous studies that showed effects of self-referential stimuli presented irrelevantly with the ongoing task when located within the focus of attention (Gronau et al., 2003; Wolford and Morrison, 1980) but not when located outside the focus of attention (Bundesen et al., 1997; Gronau et al., 2003; Laarni et al., 2000). In other words, "self effects" found in previous studies could be due to a retention of attention by important stimuli rather than to automatic attentional prioritization (see Fox, Russo, Bowles, & Dutton, 2001 for similar results with threatening words), explaining the absence of effect when they are not located in the focus of attention.

Another factor of importance determining specific attentional properties of self-referential stimuli seem to be their relationship with the ongoing task (Brédart et al., 2006; Gronau et al., 2003; Kawahara et al., 2004; Shapiro et al., 1997) and their status as target or distractor (Bundesen et al., 1997). Present data confirm this claim since the preferential allocation observed for familiar faces was modulated by the stimulus status as target or as distractor even though face identity was completely task-irrelevant. The effect of identity on total glance duration was stronger when faces were targets than when they were distractors. Present data allows interpreting previous findings further and brings new insight about visual search implying complex stimuli. First, only task-relevant features - e.g., here the shape of the mouth, the colour of the items in Bundesen et al. (1997) and in Gronau et al. (2003)s' studies - would be selected and processed. At this point, if these task-relevant features do not match those defining the target, other task-irrelevant features of the item – e.g., those determining facial identity here or lexical entries in Bundesen et al. - can be easily overlooked, explaining the weaker effect of the self-face as distractor as well as the absence of effect of distractors in other studies where distractors' features never matched the primary task (Bundesen et al., 1997). When the task-relevant features match those defining the target then the attention engages on this stimulus before the observer decides that she has found the target. This is confirmed by present data showing that targets were overall fixated about twice as long as distractors. This engagement of attention might reflect a checking process before the response is given, allowing a deeper processing of the stimulus and as a consequence of its task-irrelevant features. These task-irrelevant features can have a distractive power triggering an even longer retention of attention when they are highly familiar to the observer as shown by present data.

In conclusion, we found that a unique and distinctive self-referential stimulus such as the self-face is not systematically prioritized in comparison to another highly familiar face or even by comparison with a less important unfamiliar face. Moreover, we demonstrated for the first time that once the self-face is fixated, it holds attention as it seems more difficult to disengage attention from it than from a less familiar face. Importantly however, this effect was dependent upon the status of the face as target and similar effects were observed with another highly familiar face.

Acknowledgments

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Chapter 9

GENERAL DISCUSSION

1. Summary and discussion of present findings

In this thesis we asked the question of the specificity of a highly distinctive self-referential stimulus, the self-face. Indeed, the literature was still unclear as regard with the specificity of self-referential stimuli. Intuitively one would hypothesize that the information relative to his or her own person must be processed in a special way by comparison with less personal and important information. However, this assumption is still highly debated in the literature and some researchers have suggested that this assumption might not be true (see Gillihan & Farah, 2005 for a review).

Therefore, in the present thesis, we have conducted five studies examining whether the self-face is processed in a special way by comparison with other faces. We have put three main questions: (1) how accurate is the representation of the self-face in memory?; (2) is this representation subtended by specific neural correlates?; and (3) does the self-face have special abilities to attract and/or to hold attention?

Throughout this work, we chose to use the self-face because, by contrast with most self-referential stimuli, it is highly distinctive and unique to each person. Moreover, the self-face can be presented in the visual modality and, as a consequence, studied in a virtual infinite number of paradigms. Importantly, in order to allow an interpretation of possible effects as resulting from the ‘self’ property of the self-face rather than resulting from other factors such as the high familiarity of the self-face, we always compared the patterns of performance obtained with the self-face to those obtained with another personally familiar face. Our studies and their results are summarized and discussed below.

1.1. Self-face and memory

In a first study (see Chapter 4), we used a psychophysical method to examine the extent to which we represent our own face accurately. Indeed, this aspect of memory of the self-face had been largely neglected (for an exception see Thompson, 2002) and was still unknown. Previous studies that examined the way the self-face is represented in memory usually focused on the orientation of the representation (i.e. mirror-oriented versus normal view, see Brady et al., 2005; Mita et al., 1977; Rhodes, 1986), on the canonical view of the self-face (Laeng & Rouw, 2001; Troje & Kersten, 1999) or, on the features used to recognize its usual orientation (Brédart, 2003). Overall, these studies showed that, unlike faces of other familiar persons, the canonical view for our own face is a frontal view. Moreover, our own face is represented with a mirror-orientation. This probably arises from the fact that we cannot see our own face directly and that we need mirrors, pictures or videos. As we mostly see our own face in the mirror with a frontal view, we simply represented it the way we usually perceive it. This is actually the same with other familiar faces that we rather represent in a normal oriented-view, which is the way we mainly encounter them. In that sense, the perceptual representation of the self-face is thus not really special.

In our study, we assessed the precision of the representation of our own face. To do so, we created a set of 18 modified pictures for each participant's face. The modification consisted in increasing or decreasing the interocular distance by steps of two pixels (up to 18 pixels, on a horizontal axis, in each direction). These altered pictures and the original picture of the participant's face were presented in a random order and participants were to judge from memory whether each picture was intact or altered. Each participant also performed the same task with pictures of a friend's face. Moreover, we compared the performance of our participants to that of another group of participants instructed to perform a perceptive discrimination task. In this control task, two pictures (i.e. an original picture and another one, either original or altered) were presented simultaneously and participants were to judge whether both pictures were identical or not.

Results showed that participants were as accurate at picking out their intact own face from memory as other participants involved in a perceptual discrimination task. Moreover, the just noticeable differences (i.e. the modification necessary to judge that a face is altered in 75%

of the cases) were similar in the memory and in the perceptual discrimination task. This indicates that even if we only access a restricted range of views of our own face, the precision of its representation and the accuracy with which we can recognise it are only limited by the acuity of our visual system. This study also suggests that the physical constraints characterizing the perception of our own face do not affect much the accuracy of its representation. Indeed, participants had similar performance with their own face and with their friend's face.

This study thus brings new information about the representation of one's own face. It suggests that the accuracy of the representation of one's own face is not special. This runs against the idea that we should be especially good at recognising our own face (see Heatherton, 2004). In addition, this study also informs us about the memory for highly familiar faces in a different way than previous studies. Most of these studies used methods giving information about familiar faces by comparison with unfamiliar faces. In some tasks, participants had to explicitly recognize and/or identify familiar faces for instance by naming familiar faces or by judging whether faces presented among novel faces were familiar or not. In other tasks, the influence of the familiarity of the faces was assessed by comparing performance on familiar and unfamiliar faces in tasks that did not require an explicit recognition or identification (e.g., matching two pictures of the same person or faces presented in different orientations). Such methods gave information about people's ability to recognize the global appearance of familiar faces and about the parameters (e.g., the orientation) or information (e.g. external traits versus internal traits) that facilitate the processing of the face. The method we used was different in that people had to recognize the *real* face of a person among other pictures of the same person that had been modified. This allowed a precise examination of the accuracy of the memory for one's own face and other familiar faces.

However, this method also has some limitations. Indeed, it implied the displacement (i.e. modification of facial configuration) of one single facial feature. We displaced the eyes because they constitute an important component in facial recognition (e.g., O'Donnell & Bruce, 2001) and to replicate Ge et al. (2003)'s method. Yet, it is possible that results would have been different with displacement of other facial features. For instance, a recent study

(Brooks & Kemp, 2007) demonstrated that people perform at chance when they have to detect displacements of the ears of personally familiar faces. Therefore, it is possible that this high accuracy found for the detection of eyes displacement do not generalize to all kinds of facial manipulations.

Consistently, another study conducted in our lab (Devue, 2004) showed that the accuracy of the memory for highly familiar faces can be affected by other factors than the physical properties of our visual system (visual acuity). In that study we displaced the inner features (eyebrows, eyes, nose and mouth) upwards or downwards. The latter alteration gave rise to facial configurations similar to that existing when the person was younger (see e.g. Berry & McArthur, 1986; Montepare & Zebrowitz, 1998) whereas the former gave rise to novel facial configurations that the face had never presented. With such facial alterations, participants tended to accept as unaltered faces with inner features moved downwards more than faces with inner features moved upwards. This result held for the participants' own face as well as for other personally familiar faces. By contrast, this asymmetry was not present among participants performing a perceptual discrimination control task. In that case, there was no difference in the detection of upwards or downwards displacements. This study thus indicated that the representation of familiar faces in memory is not just a photograph that we can access to order. Rather, this representation can be influenced by parameters such as the past appearance of the face. Contrary to the vertical position of the inner features, the relative distance between one's eyes is quite constant throughout facial development. This probably accounts for the high accuracy found when observers have to detect alterations of the interocular distance.

Finally, another reason explaining that we did not find any difference between the self-face and other familiar faces regarding their representation in memory could be that we focused on configural perceptual aspects. It is feasible that differences would have emerged if we had examined more qualitative or emotional aspects of memory.

For instance, responses could differ between one's own face and other familiar faces if participants were instructed to subjectively judge from memory different aspects of faces (e.g. their attractiveness, their distinctiveness, etc). Moreover, recent studies have shown that the processing of identity and the processing of emotional expressions are not independent in familiar faces (Ganel & Goshen-Gottstein, 2004; Kaufmann & Schweinberger, 2004). More specifically, participants that were to make a speeded familiarity judgment on novel faces and famous faces that had been morphed from a angry to a happy facial expression were influenced by the emotional expression in famous faces but not in unfamiliar faces (Kaufmann & Schweinberger, 2004). The judgment was faster when famous faces depicted a moderately happy expression. This suggests that representation of faces in memory include information about people's typical expression. As it has been proposed that a neutral representation of our own face (as seen in the mirror) and a happy representation of our own face (as usually seen on pictures) might compete (see Rhodes, 1986), it is possible that, in such a task, the fastest responses would be observed with stimuli depicting a more neutral expression for the self-face than for another highly familiar face. This could be tested in future work by acquiring pictures of participants while they express various emotional facial expressions. The difficulty, however, would precisely be to elicit such expressions naturally and similarly in all participants. By contrast, explicitly ask participants to change their emotional facial expressions to order would give rise to unnatural facial expressions. A solution might consist in filming participants while they view pictures of emotional facial expressions and exploit the phenomenon of facial mimicry (see e.g., Moody, McIntosh, Mann, & Weisser, 2007). Snapshots of participants depicting the target facial expressions would then be extracted from the videos.

In sum, we investigated one aspect of the representation in memory of one's own face, the interocular distance. We found that, in that regard, the representation of one's own face is very accurate but is not special by comparison with other familiar faces. Future work should examine other facial dimensions to determine the extent to which this result generalises to the whole face or not. Moreover, future work should also investigate more emotional aspects relative to the representation of one's own face.

1.2. Neural correlates of visual self-recognition

In a second study (see Chapter 5), we asked whether self-recognition is subtended by specific neural correlates by comparison with the recognition of other personally familiar persons. We tried to develop a new methodology aimed at determining the neural correlates of visual self-recognition. Indeed, the hemispheric dominance as well as the precise anatomical location devoted to self-face recognition was still debated in the literature (see Section 3 of Chapter 2).

Self-face recognition

Thus, our study was first motivated by the lack of consensus as regard with the neural correlates of self-face recognition. Moreover, previous studies had several limitations that we wanted to address. Therefore, we designed a task in which participants had to identify their intact face among a set of intact and altered pictures. The alteration was identical to that used in Chapter 4, that is, a horizontal displacement of the eyes. The pictures of each participant and pictures of the face of a participant's friend were presented in a random order within an event-related scanning session. As a consequence, participants were forced to identify the face before they can decide if it has been altered or not. We analysed cerebral changes while participants recognised their real facial appearance. Hence, this task differed from task used in previous studies in which participants processed morphed images of the self-face (e.g. Keenan, Wheeler, Platek, et al., 2003; Kircher et al., 2000, 2001; Turk et al., 2002; Uddin, Kaplan, et al., 2005; Uddin et al., 2006). Indeed, these morphed pictures blend one's own face with other faces and therefore, their processing might not reflect the usual processing of one's own face. Moreover, our study implied a task giving rise to observable responses contrary to other studies in which participants were simply instructed to think about the person depicted on a picture (Platek, Keenan, et al., 2004). A last advantage of using intact and altered pictures was that it introduced variability in the stimuli and hence prevented a too fast habituation of the cerebral response to the pictures.

We found that recognising one's own face specifically involved the right inferior frontal gyrus and of the right insula by comparison with recognising another highly familiar face. The implication of the right inferior frontal gyrus is in line with previous studies reporting implication of this region in the distinction between self and others (Uddin, Kaplan, et al., 2005) or in the attentive processing of the self-face (Sugiura et al., 2000). The right (Kircher et al., 2000, 2001) and the left insula (Sugiura et al., 2000) had been found to be implied during self-face recognition. The insula was attributed a role in the sustained attention to the representation of the self-face (Sugiura et al., 2000). In sum, our results are rather consistent with a right hemispheric dominance model of self-recognition (Keenan, Wheeler, et al., 2000, Keenan, Wheeler, & Ewers, 2003; Platek, Keenan, et al., 2004; Platek et al., 2006).

By contrast, the recognition of the other familiar face elicited specific activation in the superior temporal gyrus in both hemispheres and in the left precuneus by comparison with the recognition of the self-face. Actually, activity was reduced for both the self-face and the other familiar face in these regions but the deactivation was less important for the colleague's face than for the self-face. This result is consistent with those of several previous studies reporting more reduced activation in the temporoparietal junction (Sugiura et al., 2005), in the left superior temporal gyrus and in the precuneus (Uddin, Kaplan, et al., 2005) for the self-face than for other familiar faces. This result could arise from the fact that these regions contain the representation of people's names and therefore that they are less likely to react when processing one's own face than when processing familiar persons' faces (Sugiura et al., 2005). Another study interested in the neural correlates of highly relevant persons presented mothers with pictures of their children and of their best friend (Bartels & Zeki, 2004). This study also showed deactivation in some regions (parieto-occipital junction, superior temporal sulcus, middle prefrontal cortex, paracingulate cortex, temporal poles, posterior cingulate gyrus, medial cuneus and amygdaloid region) during the processing of the relevant faces. The authors attributed these deactivations to a diminution of negative emotions, social judgment and theory of mind with which these regions are associated. It is possible that these socially related processes also decreased more when viewing oneself than when viewing another familiar person.

Self-body recognition

A second aim of our study was to examine the neural correlates of another part of one's own physical appearance, the headless body. Indeed, at that time there was no study investigating neural correlates of self-body recognition (see Gillihan & Farah, 2005) with the exception of a study by Kurosaki and colleagues (2006). However these authors focused on the processing of altered bodies. Moreover, in their study, faces were not hidden and it was thus difficult to conclude that the regions they found were only devoted to the processing of bodies. These regions could also have been activated by the processing of faces (note that the same comment applies to other studies such as that by Sugiura et al., 2006).

In order to collect comparable data between faces and bodies, we used the same method as that used with faces in a second event-related scanning session. We presented at random intact and altered pictures of our participants' own body and of the body of another personally familiar person. We chose a bodily alteration as similar as possible to that applied to faces. We modified the waist-to-hip ratio by increasing or decreasing the width of the hips. Therefore, this alteration was on a horizontal axis and affected a relevant part of the stimulus, giving rise to easily detectable but plausible new bodily configurations. Participants were to perform an 'intact-altered' judgment on this set of pictures.

We found that the right cingulate gyrus and a large frontal area on the right side were implicated in the recognition of the self-body. This is in line with results that we found with faces and with previous studies investigating self-face processing (Keenan, Wheeler, & Ewers, 2003, Kircher et al., 2000; Platek, Keenan, et al., 2004; Platek et al., 2006; Sugiura et al., 2000; Uddin, Kaplan, et al., 2005). The insula was also implicated in self-body recognition but on the left side. However, activations were less reliable with bodies than with faces. This could result from person identification being less easy from bodies than from faces leading to less sensible activation. Consistently, reaction times indicated that participants were faster with faces than with bodies.

Abstract self-recognition

Third, we were interested in neural correlates subtending visual self-recognition independently of the stimulus domain. As we designed a study in which the self-face and the self-body were presented and judged by participants in comparable conditions, we were able to examine the existence of cerebral areas especially devoted to an abstract visual self-recognition independent of the type of material presented. We collapsed data obtained with faces and data obtained with bodies and compared the cerebral areas implied during the processing of self-related stimuli to those implied during the processing of stimuli related to another highly familiar person.

Here, results showed an implication of the right anterior insula and of the right dorsal anterior cingulate during processing of self-related pictures. The implication of the anterior cingulate is in agreement with the claim that this structure might be generally involved during abstract self-processing (i.e., independent of the stimulus domain or of the sensorial modality) or when making decisions about self-referential information (Northoff & Bermpohl, 2004; Platek et al., 2005). Indeed, the insula has been found to be implicated in different aspects of self-processing such as self-agency (Farrer & Frith, 2002), autobiographical episodic memory retrieval (Fink et al., 1996), self-face recognition or self-descriptive judgments (Kircher et al., 2000, 2001). In sum, present results combined to those of previous studies suggest that the anterior cingulate and the right anterior insula could play a general role in making decisions about oneself.

Note that, unlike previous empirical studies or integrative works that tried to infer neural correlates of self-processing by comparing data obtained in different tasks and with different methods, our method allowed a comparison of two types of self-recognition investigated with the same procedure.

General face and body processing

Our study also had the secondary goal of comparing cerebral areas associated with the general processing of faces to those associated with the general processing of bodies. To do so, we added two control sessions following the two experimental sessions devoted to the investigation of self-face and self-body recognition. In a first control session, we presented the intact picture of the participant’s face and the same picture that had been scrambled. Pictures of faces and scrambled pictures thus had the same low level properties with the former having a facial structure and the latter having no meaning. These pictures were presented at random and were preceded by a coloured fixation cross. The cross was red in 87.5% of trials and yellow in the remaining 12.5% of trials. Participants were instructed to report yellow crosses by pressing a response key. This procedure allowed us to ensure that the participants were attending to the stimuli. In a second control session, the same method was used with pictures of the participant's body.

Results indicated that the processing of faces and the processing of bodies seem to recruit close but segregated areas of the occipital cortex. In addition, it seemed that there is a common implication of the right fusiform gyrus for face and body processing. These results are in agreement with previous studies that demonstrated that distinct regions of the extrastriate cortex are specifically devoted to faces (ventral occipital face area, OFA, Puce et al., 1996; Peelen & Downing, 2005) and bodies (extrastriate body area, EBA, Downing et al., 2001; Peelen & Downing, 2005). Moreover, recent studies (Peelen & Downing, 2005; Schwarzlose et al., 2005) also found that distinct but overlapping regions of the fusiform gyrus were associated with presentation of faces and bodies.

Neural correlates of person identification

From all abovementioned results we attempted to develop a general model of visual person recognition. Overall, our data indicated that posterior and anterior regions play specific roles in person identification. At a first level of processing, posterior regions (i.e., occipito-temporal cortex) would intervene in the distinction of different aspects of persons (i.e., classification as face or body). Then, the fusiform gyrus could be implied in a more elaborated structural encoding of the different body parts and provide a first evaluation of the person's familiarity (see Rossion et al., 2003). After that, anterior regions (i.e., mainly the frontal and superior temporal cortices, the anterior cingulate cortex and the anterior insula) may serve to access more abstract information about identity of familiar individuals (e.g. semantic information about these persons and their names). More specifically, the anterior insula and the anterior cingulate cortex would distinguish oneself from others and give rise to an abstract representation of oneself.

Conclusion, limitations and perspectives

In sum, this study showed that specific cortical regions, mainly the right frontal cortex and the insula, are implicated in visual self-recognition. These results support the claim that the right frontal cortex preferentially intervenes during self-recognition (Keenan, Wheeler, et al., 2000, 2001; Platek, Keenan, et al., 2004). Moreover, it seems that anterior regions within the right hemisphere (i.e., the anterior insula and the dorsal anterior cingulate) are implicated in the distinction between the self and others and in a more abstract representation of the self.

However, the fact that our participants were all females may limit the generalisation of our results. More specifically, regarding body processing, the study by Kurosaki et al. (2006) showed that differences exist between men and women when they are processing altered images of their own-body. It is possible that such gender differences applied to the processing of intact images of one's own body. One's own face processing might also be concerned with such gender differences. Future work should thus attend to this issue and include male as well as female participants in their sample.

1.3. Self-face and attention

After having shown that the representation of our own face in memory is not special (at least regarding its accuracy) whereas it is subtended by specific neural correlates, we asked, in a set of three studies, whether the self-face is particularly prone to capture and/or hold attention.

For fifty years (Moray, 1958) it has been claimed that referential stimuli (e.g., one's own name) are particularly prone to attract attention because of their meaning and of their importance (e.g., Mack & Rock, 1998). However, this assumption has later been questioned by other studies demonstrating that one's own name does not automatically capture attention (e.g., Bundesen et al., 1997; see Section 4 of Chapter 2).

Therefore, in a set of three studies (see Chapters 6 to 8), we examined the precise conditions in which self-referential stimuli have (or do not have) specific attentional properties. Here again, and by contrast with most of previous studies, we used the self-face because, contrary to one's own name, it is a unique and distinctive self-referential stimulus. In addition, in order to disentangle possible self-effects from mere familiarity effects we compared the patterns of results elicited by the presentation of the self-face to those elicited by the presentation of another highly familiar face. Indeed, we hypothesised that familiarity effects could be sufficient to explain some finding of previous studies.

Digit-parity paradigm

We conducted a first study (see Chapter 6) aimed at examining whether the self-face is prone to produce a distraction when it is presented irrelevantly with the task at hand, whether this distraction is robust or only temporary and whether it is dependent upon the location of the self-face within the observer's focus of attention. We used a paradigm that had been used with one's own name (Harris & Pashler, 2004; Wolford & Morrison, 1980) and adapted it to take possible familiarity effects into account (i.e., we compared the distraction caused by the self-face to that caused by another highly familiar face). In the original paradigm, participants had to perform a digit-parity task while ignoring words presented between the two digits.

In a first experiment, we replaced words by pictures of faces. By analogy with Harris and Pashler (2004)'s study, familiar faces were presented infrequently in a first block of trials (i.e. the self-face and a friend's face appeared once each; unfamiliar faces appeared on the other trials). This first block assessed the reaction to the self-face after its first apparition (e.g., surprise reaction). Then, in a second block of trials, familiar faces appeared more frequently, on half of the trials. This second block determined whether the response to the self-face carries on after several presentations or if it is only transient.

In this first experiment, we found that the first occurrences of both familiar faces interfered with the digit-parity task when the faces were presented within the participants' focus of attention. However, this effect was only temporary and participants seemed to habituate to seeing their own face as well as their friend's face. Indeed, after a few presentations, reaction times elicited in trials in which familiar faces were presented were similar to reaction times for trials showing unfamiliar faces. This first experiment thus extends Harris and Pashler (2004)'s findings (i.e., one's own name have no enduring capacity to attract attention) to a highly distinctive self-referential stimulus. Moreover, it also shows that the self-face is not really special since similar results were obtained with another highly familiar face.

In a second experiment, we presented distractor faces at periphery, on the right or on the left of the two digits. Based upon findings by Gronau et al. (2003) with the own name we hypothesised that familiar faces should produce no distraction when they were presented at periphery because their processing was not necessary for the ongoing digit-parity task. Results showed that the distractive ability of the two familiar faces was reduced when they were presented at periphery, presumably outside the participant's attentional focus. Indeed, they produced no distraction after their first apparitions. In addition, they overall produced no significant distraction in the second block of trials. Nonetheless, a sharper analysis of this second block of trials revealed that the friend's face was more distractive than unfamiliar faces in the first part of Block 2 but that this response habituated in the second part of Block 2. By contrast, the presentation of the self-face had no significant effect. This indicated that the self-face does not automatically capture attention. The small effect obtained with the friend's face was a bit unexpected (see Gronau et al., 2003). It suggested that participants shifted their attention at periphery after a few dozen of trials, when they mastered the task. This elicited a distraction that quickly habituated on subsequent trials. Nonetheless, this effect was not strong enough to affect Block 2 in its entirety. Importantly, this effect also demonstrated that faces were perceivable at their peripheral location. Therefore, the absence of interference by the self-face was not due to a lack of perception of the peripheral faces.

This first study thus indicates that the self-face is not a particularly potent distractor stimulus. Indeed, the presentation of another familiar face produced overall similar results (less clear effect with the friend's face than with the self-face in Block 2 of Experiment 1 and clearer effect in Block 2 of Experiment 2). Moreover, the distraction produced by both faces was of short duration and was affected by the presentation within the participant's focus of attention. This suggests that when the familiar faces are presented in a way so that they are difficult to ignore (i.e., centrally, see Beck & Lavie, 2005) they only elicit a surprise reaction that quickly disappears. In addition, our second experiment suggests that a familiar face does not automatically capture attention since its presentation at periphery had an effect only after several presentations. These results could indicate that the interference produced by familiar faces is not due to a capture of attention but rather to a transient difficulty to disengage attention from these faces once they are attended (for a similar rationale with threatening words, see Fox et al., 2001).

Unfortunately the digit-parity paradigm did not allow us to break the observed interference effect down into capture and retention components of attention. In following studies, we addressed this issue by using paradigms allowing a clearer distinction between these two components of attention.

Inattentional blindness paradigm

In a second study (see Chapter 7), we more directly assessed whether the self-face captures attention by comparison with other faces. We used the inattentional blindness paradigm originally designed by Mack and Rock (1998). In the variant of the paradigm that we used, a critical stimulus is presented very briefly and unexpectedly within the observer's visual field (i.e., at fixation) while he/she is engaged in another attentional demanding task. This task consists in judging which arm of a large cross appearing briefly around fixation is longer compared to the other one. After three trials in which the large cross has been presented alone, there is a first critical trial (i.e. inattention trial) in which the critical stimulus is presented besides the large cross. Inattentional blindness (IB) is said to occur when the observer fails to detect the presence of the critical stimulus.

First, we replicate, with photographic stimuli, Mack and Rock (1998)'s finding that faces capture attention and resist more to blindness than other stimuli. In Experiment 1 we presented pictures of neutral faces as critical stimuli. We compared their capacity to be detected to that of other common objects (i.e. fruits and vegetables). We found that faces were more resistant to blindness than objects since the former were detected more frequently than the latter. In addition, we evaluated how accurate observers were at recognising the critical stimuli that had been presented and found that despite their better resistance to blindness, faces were not better recognised than objects. In Experiment 2 we addressed the possibility that faces were better detected than fruits and vegetables due to their low level properties rather than to their meaning. We compared the capacity of upright faces and of inverted faces to resist to blindness. We replicated results of Experiment 1: upright faces were better detected than inverted faces but the former were not better recognised than the latter. This study thus suggests that the structure of a face can be analysed pre-attentively by the visual system. However, this analysis is not sufficiently elaborated to allow an accurate recognition of the individual face.

Finally, in a third experiment we assessed whether identity and familiarity of a face can affect its resistance to blindness. More specifically, we evaluated whether the self-face that combines two properties likely to attract attention (self-referential stimulus like the own name and facial structure, see Mack & Rock, 1998) is particularly resistant to blindness. We compared three types of critical stimuli: a picture of the participant's own face, a picture of the face of a participant's friend/colleague, and the picture of an unfamiliar person of the same gender as the participant. Results showed that all three faces did not differ in their capacity to capture attention (we will not rediscuss the non-significant numerical difference between the friend's face and the other faces here). Thus, this does not support the hypothesis that the self-face should capture attention more than other faces due to its self-referential properties. However, familiar faces were overall better recognised than unfamiliar faces. This indicates that once attention has been drawn by a face, familiar faces are processed more efficiently than unfamiliar faces. This probably results from the robust representation we have of familiar faces in memory (see Tong & Nakayama, 1999).

Taken together, these results suggest that the structure defining faces can be detected pre-attentively more than other stimuli since it determines their selection by attention and their perception. Nonetheless, it seems that the visual system cannot extract pre-attentively elaborated information about these faces since familiarity or identity did not affect the attentional selection.

The results of this inattentional blindness study contrast with those of the previous study using the digit-parity paradigm. Indeed, the latter showed an effect of familiar faces in attention while the former did not. A possibility to explain this apparent discrepancy is that the distraction observed in Chapter 6 did not result from an attentional capture but from a difficulty to disengage attention from familiar faces. We tested this hypothesis in the last study.

Visual search task and eye movements recording

In this study (see Chapter 8), we used a technique allowing us to control exactly which stimuli participants are overtly attending to and when they are doing so, that is the eye-movements recording. Moreover, we used a visual search task because this task takes place in an extended temporal window when it implies complex visual stimuli. Coupled with the eye-movements recording, it thus provides precise information about the different stages of attentional allocation (i.e. early capture of attention, attentional shifts, attentional disengagement, etc, see Weierich et al., in press). Hence, this study was aimed at determining precisely the way attention is allocated to the self-face.

The visual search task we designed consisted in looking for a target face pronouncing an “o” among distractor faces pronouncing an “m” (or the other way around) on a display comprising 6 unfamiliar faces. The participant’s own face or the face of a participant’s friend could appear on some trials, as a target (i.e. “o” face) or as a distractor (i.e. “m” face), among 5 unfamiliar faces. Importantly however, it was unnecessary to identify the faces to perform the task.

We found that one’s own face was not prioritised by comparison with other faces, or in other words, that it did not capture attention. Indeed, the self-face did not receive a saccade faster than other faces. However, we demonstrated that one’s own face benefited from a preferential allocation of attention by comparison with unfamiliar faces. This was reflected by longer fixations on the self-face than on unfamiliar faces. These longer fixations on the self-face resulted in an interference effect since its presence increased response times to the visual search task. Finally, the fixation duration was modulated by the status of the self-face as target or distractor: the fixation was even longer as it was a target. The pattern of results observed with the friend’s face was similar to that obtained with the self-face even if the friend’s face sometimes produced performance situated between the self-face and unfamiliar faces.

Self-face and attention

Overall, results of these three studies are quite consistent. They all suggest that the self-face is not a potent distractor and that it does not capture attention (see especially Chapter 7). Rather, it seems that the self-face is fixated longer than unfamiliar faces only once it is located within the observer's focus of attention and attended (see Chapter 6 and 8). In other words, self-effects in attention could just reflect a preferential allocation of attention in favour of self-referential stimuli rather than an attentional capture.

In our opinion, this finding could resolve apparent inconsistencies in previous studies. Indeed, it has been shown that the irrelevant presentation of self-referential stimuli interferes with the ongoing task when they appear within the focus of attention (Gronau et al., 2003; Wolford & Morrison, 1980) but not when they appear outside the focus of attention (Bundesen et al., 1997; Gronau et al., 2003; Laarni et al., 2000). Therefore, "self effects" found previously could be due to a retention of attention by self-referential stimuli rather than to an automatic attentional capture. This would explain the absence of effect when self-referential stimuli are not located in the observer's focus of attention.

Another factor determining the attentional selection of self-referential stimuli seem to be their relationship with the ongoing task (Gronau et al., 2003; Kawahara et al., 2004) as well as their status as target or distractor (Bundesen et al., 1997). Results of our eye-movement study confirm this claim since the sustained fixations observed for the self-face was modulated by its status of target or of distractor. Indeed, the time spent fixating the self-face was longer when it was a target than when it was a distractor.

Moreover, the longer fixations on familiar faces affected reaction times so that participants were slower when a familiar face was present among the 6-faces display than when only unfamiliar faces were presented. This result differs from those of other visual search studies showing that one's own face is detected faster than other faces (e.g. Tong & Nakayama, 1999; see also Mack & Rock, 1998 for similar findings with one's own name, but see Harris et al., 2004) and that could suggest that the self-face capture attention. However, we have to stress here that in our three studies the self-face was presented irrelevantly for the task at hand. In addition, in our visual search study, the target was not defined by facial identity but by other facial features (i.e. the shape of the mouth determining the speech-sound pronounced by the face). By contrast, in the study by Tong and Nakayama (1999), the participant's own face was the target to search for among unfamiliar faces. In other words, the search concerned facial identity. Therefore, these opposite patterns of results (i.e. increased RTs in our study and reduced RTs in Tong & Nakayama's study) could be explained by the different attentional set in which participants were (as shown with one's own name by Kawahara et al., 2004) and by the features defining the target (i.e., mouth configuration in our study and identity in Tong & Nakayama's study). To assess this hypothesis, we could use the same procedure as that we used in our eye movements study but change the observer's attentional set. The target would be defined by facial features determining identity rather than by features independent of identity. In these conditions, one's own face should be detected faster than another face (see Tong & Nakayama, 1999). In addition, eye movements recording would indicate whether the self-face is advantaged because it receives the first saccade faster than other faces and/or because it is fixated during a shorter time than other faces (i.e., for it is easier to recognize).

The results of our three studies allow us to interpret previous findings about the attentional properties of self-referential stimuli further and bring new insight about the attentional selection of complex stimuli. It seems that the self-face does not capture attention, at least when its processing as a self-referential stimulus is not relevant for the task at hand[17]. This suggests that the visual system is not tuned to automatically detect self-referential stimuli. By contrast, it seems that the visual system can differentiate faces and non-faces pre-attentively since the facial structure of a stimulus determines its selection by attention (see Chapter 7). In sum, our results suggest that attention and foveal inspection are necessary to process the facial features determining identity (see Underwood, Templeman, Lamming, & Foulsham, in press, for similar finding with scenes perception).

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[17] Note that the processing of the self-face could nonetheless be prioritised when the task implies the identification of the self-face. The self-face could even capture attention in such a task if attentional capture is contingent on task set with complex stimuli as it is the case with simpler stimuli (see e.g. Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994; but see Schreij, Owens, & Theeuwes, 2008). This point should be addressed in future work.

In the context of *visual search* implying complex visual stimuli (see Chapter 8), it seems that at first, only task-relevant features (e.g., the shape of the mouth in our own study, the colour of the items in Bundesen et al., 1997, and in Gronau et al., 2003, s' studies) would be selected and processed. In our eye-movements study, the slow and serial aspects of the search indicated that attention was also necessary to discriminate the speech-sound pronounced by faces: faces were fixated serially until the target was found. Hence, at this stage of processing, if the task-relevant features of an item do not match those defining the target, other task-irrelevant features of the item (e.g., those determining facial identity here or lexical entries in Bundesen et al., 1997) can be easily overlooked. This would explain the weaker effect of the self-face presented as distractor by comparison with situations in which the self-face was a target, as well as the absence of effect of distractors in other studies where distractors' features never matched the features defining the target (e.g. in Bundesen et al., 1997, the distractors and the targets always had a different colour; in Laarni et al., 2000, the self-face was always presented at background and target faces at foreground). This idea is consistent with the *Input filter* theory developed by Bundesen et al. (1997). According to this theory, the observer prepares an 'input filter' to optimise his or her performance as a function of the ongoing task. This filter determines the features of a stimulus that will draw attention.

In addition, our data suggest that the complexity of the feature defining the target will determine whether the target captures attention (i.e., if the feature is perceptually simple) or whether the processing of the task-relevant feature will just be prioritised by comparison with the processing of other task-irrelevant features (i.e., if the feature is perceptually/semantically complex). To put it differently, in cases where the target is defined by low level features such as colour, the target could automatically capture attention; whereas in cases of targets defined by higher level features (meaning of a word, speech-sound pronounced by a face, etc), serial attention will probably be necessary to find the target (see e.g., Treisman & Gelade, 1980). Moreover, in that latter case, our data indicate that when the task-relevant features of an item match those defining the target, attention must engage on the stimulus before the observer decides that he/she has found the target. Indeed, targets were overall fixated about twice as long as distractors. This engagement of attention might reflect a checking process before the response is given. This attentional engagement would allow a deeper processing of the stimulus and, as a consequence, of its task-irrelevant features. These task-irrelevant features can have a distractive power triggering an even longer retention of attention when they are highly familiar to the observer, as shown by our eye-movements data.

Future work should assess the extent to which attention is necessary for different types of categorisation of faces. Apparently, attention is not necessary to discriminate face from non-face whereas it is necessary to discriminate different persons from each other. Then, it would be interesting to examine which types of facial categorisations (e.g., gender, race, emotional expression, or age judgment) require attention. For instance, whether or not different emotional facial expressions can be processed pre-attentively is still debated (for a review, see Weierich et al., in press).

In sum, our experiments indicated that one's own face does not have special attentional properties by comparison with other highly familiar faces. Moreover, our experiments showed that the self-face can constitute an interesting tool of investigation in the field of visual attention. Our data bring new elements about the way the selection of attention proceeds. They all suggest that an elaborated processing of a complex visual stimulus, for instance in terms of identification, is not possible without attention (see Lachter et al., 2004). This finding runs against the late selection theory of attention according to which the meaning of the stimuli is processed before the selection of attention occurs (Deutsch & Deutsch, 1963). It seems that our results rather support an early selection theory of attention (Broadbendt, 1958; see Harris et al., 2004 for a similar view) or more intermediate views such as, for instance, the feature integration theory developed by Treisman and Gelade (1980). Indeed, this theory argue that individual features can be extracted pre-attentively in parallel while a serial attention to each stimulus is needed to perceive these stimuli in an integrated way. A parallel can be done with this theory and our own results showing that 'simple' features defining a facial structure can be extracted pre-attentively whereas serial attention is needed to extract more complex facial information (e.g., the speech sound pronounced by the face or its identity).

1.4. Integration of present findings

The main question asked in this thesis was «do we process our own face differently from other faces?». We have attempted to answer that question from three different perspectives by comparing the self-face and other highly familiar faces. In terms of precision of the perceptual representation in memory, our own face does not seem special. Overall, it does not seem special either as regard with its potency to attract or hold attention. The only case in which we found specificities for our own face concerned its neural correlates.

Discrepancy between neuroimaging data and behavioural data?

One might ask why this particularity at the cerebral level found in the neuroimaging study was not reflected in the behavioural studies. In the case of our first study (see Chapter 4), a possible reason for that apparent inconsistency could be that we investigated too "low level" components of the facial processing, that is a structural encoding stage. Indeed, it is possible that common cerebral areas (e.g., the fusiform gyrus, see Chapter 5) intervened in the "intact-altered" judgment for both familiar faces. Remember that the presentation of the two types of familiar faces was blocked in our psychophysical experiment whereas it was mixed in our fMRI study. Therefore, at the beginning of each block, the participant knew which face would be presented throughout the block and it was not necessary to process the facial identity at each trial (by contrast, in the fMRI study, participants had first to discriminate the self-face from the friend's face at each trial before they could respond). Moreover, it is plausible that perceiving one's own face triggered emotional or evaluative judgments (e.g., 'I look very bad on this picture'), giving rise to specific cerebral activations for the self-face by comparison with other familiar faces, and highlited by the fMRI study, but that were not reflected at the behavioural level because these processes did not affect the realisation of the task at hand.

In our three studies investigating the attentional properties of the self-face, the processing of the self-face as a self-referential stimulus was also unnecessary to the successful realisation of the tasks. In the study using the inattentional blindness paradigm (see Chapter 7), we could not find any differences between the self-face, another highly familiar faces and unfamiliar faces as regard with their relative attention-grabbing capacity. By contrast, faces differed from non-face in their ability to capture attention. Our fMRI study suggests that this pre-attentive analysis of the facial structure could take place in occipito-temporal regions. Then, once attention is focused on the facial stimulus, the fusiform gyrus and more anterior regions would be implicated in a finer perceptual analysis of the face in order to extract identity and allowing the subsequent recognition of the stimulus. Apparently, in the inattentional blindness study, this analysis was more efficient for familiar faces than for novel faces since the former were better recognised than the latter. However, it seems that this perceptual analysis was not efficient in all cases. Indeed, participants that reported the presence of an additional stimulus when they were presented with their self-face did not necessarily report that they saw this particular face. There are two alternative explanations for these results (corresponding to the two opposite theories of attentional selection). First, the self-face *is not special* in terms of attentional capture. In that case, even if facial familiarity/identity was accessible pre-attentively (as hypothesised by the late selection theory of attention), the self-face would not be advantaged more than any other faces by the visual system in terms of attentional selection. Second, the absence of difference between the three types of faces could result of the necessity to process faces attentively to extract familiarity and identity information (as would be hypothesised by an early selection theory of attention). In other words, the self-face *could not be special* in terms of attentional capture because it is not discriminated from other faces before it is attended, and therefore, cannot be better detected than other faces. The results of our two other studies about attention (see Chapter 6 and Chapter 8) seem in favour of the second alternative.

Indeed, in these studies, both types of familiar faces elicited differential responses by comparison with unfamiliar faces. They did so only in some specific conditions which suggest that familiar and self-referential faces do not automatically capture attention. Notably, it seems that participants preferred to attend to familiar faces than to unfamiliar faces, but only once they were fixated. This means that the familiarity of faces was processed by the visual system but at an attentive stage of processing. However, there were no noticeable differences between the self-face and other highly familiar faces. This could be because the self-face was not processed in a highly elaborated way and because regions such as the right insula or the right prefrontal cortex did not intervene in its processing (see Chapter 5; see also Sugiura et al., 2001). Indeed, the tasks we used did not require such a highly elaborated processing of the faces or processes of a more subjective or affective nature. Rather, the tasks did not allow much time to process the faces and they might consume the attentional resources necessary to an elaborated processing of the self-face. Nonetheless, an interesting mean to assess the extent to which the self-face was processed as a self-referential stimulus during such tasks would be to use functional magnetic resonance imaging. Indeed, a specific implication of cerebral areas devoted to the processing of self-referential stimuli during the presentation of the self-face as an irrelevant distractor would be an indication that it is processed as the self-face by the brain and not simply as a familiar stimulus. However, we have seen that, at the behavioural level, the response to the irrelevant presentation of the self-face habituates quickly (see Chapter 6). This might be an issue with fMRI because this technique implies the presentation of a large number of trials per condition in order to obtain enough sensitivity. A solution could consist in increasing the variability of the stimuli by presenting participants with different pictures of their own face.

Implications for the study of self-consciousness

We began this thesis by questioning the possibility of studying self-consciousness with self-referential stimuli. We argued that a lack of specificity of self-referential stimuli by comparison with other highly familiar stimuli might question their use for a proper evaluation of self-consciousness. So what is the implication of our finding for the study of self-consciousness?

In Chapter 1 we developed the idea that self-consciousness covers multiple aspects and that self-recognition is just one dimension of self-consciousness. We have seen that in cases of non-verbal organisms (e.g. infants or animals), the presentation of the self-face in mirror or in pictures can be a useful way, not to say the only way, to examine whether they have some abilities related to self-consciousness. In this thesis, we studied healthy human adults. In our behavioural studies, we found that the self-face is not processed as a particular kind of stimulus. More precisely, we could not demonstrate any unequivocal specific treatment of the self-face when properly matched to a colleague's face. Therefore, at the behavioural level, the presentation of the self-face might not be the most efficient way to study self-consciousness in healthy human adults. Of course, the ability to recognise that a picture of oneself depict one’s own face entails self-consciousness. Obviously, an organism incapable of self-recognition could not detect alterations brought to pictures of its face or would most likely not react to the unexpected presentation of pictures of its face. So, even if our tasks entailed self-recognition, we did not directly measure self-consciousness per se (note that this was not our purpose since this thesis aimed at evaluating whether the self-face is a special face). In addition, the exclusive use of the self-face does not allow the study of the many other components of self-consciousness and higher-level aspects of self-consciousness such as for instance one’s own personal aspirations or the consciousness of one’s own emotions. In the healthy human adults, there are many other ways to investigate self-consciousness than just presenting participants with their own face.

By contrast with what we observed at the behavioural level, our neuroimaging study showed specific cerebral responses elicited by the presentation of self-related stimuli. Therefore, the presentation of the self-face can be a useful way to investigate self-consciousness from a neuroscientific point of view, even in healthy adults. Moreover, in our fMRI study, the combined presentation of the self-face and of the self-body allowed us to examine a more abstract form of self-recognition. However, at the risk of being redundant, if the visual presentation of one’s own body parts probably allow the study of neural correlates of one’s own physical appearance, the implication of the activated cerebral areas in all components of self-consciousness remains hypothetical.

In sum, beyond the ambitious and probably elusive aim of studying self-consciousness in its entirety, we think that the presentation of the self-face can constitutes an interesting tool of investigation in several situations. In the healthy human adult it can bring information about the neural correlates of the self-recognition component of self-consciousness. With non-verbal organisms, differential processing of the self-face is a clue that the organism has at least some low level self-related abilities. In post-comatose patients, the mirror is also a particularly important tool to discriminate patients that are in a minimal conscious state from those that are in a vegetative state. Indeed, MSC patients are particularly prone to pursue their reflection in a mirror by comparison with other objects (Vanhaudenhuyse, Schnakers, Brédart, & Laureys, 2008). However, whether this visual pursuit reflects self-consciousness is still a matter of debate. Therefore, in such cases, it is probably wiser to consider the self-face as a stimulus with a high capacity to elicit a response rather than as a direct measure of self-consciousness.

Implications for the study of other cognitive processes

The studies presented in this thesis also indicate that pictures of the self-face can offer interesting opportunities to study various cognitive functions. For instance, in the domain of the visual recognition of complex stimuli, the self-face constitutes a special type of stimulus because we encounter it only in specific situations by comparison with other items of the same category (i.e., faces). However, there are other stimuli that have their own specificities or that are special only for some individuals. Researches about expertise have shown that experts do not process the subjects of their expertise in the same manner as novices (see e.g. Diamond & Carey, 1986). Therefore, the self-face could be used as a tool to investigate visual recognition besides other types of stimuli (i.e. faces or “Greebles”, see Gauthier, Williams, Tarr, & Tanaka, 1998).

In the domain of selective attention, the self-face also constitutes a very interesting tool of investigation. Because it is a very specific type of face, its presentation among other kinds of faces allows researchers to examine the level of complexity of information the visual system can extract (pre-attentively or attentively) about a stimulus and in which conditions. Other researchers have used various types of stimuli with the same purpose (e.g., scenes, words, emotional pictures, threatening stimuli with anxious individuals, etc). A recent eye movement study has shown that arachnophobic participants detected spiders faster than controls in a visual search task but that they subsequently avoided fixating the spiders more than controls (Pflugshaupt et al., 2005). These patterns of results thus seems opposite to what we have observed with one’s own face (i.e. no detection advantage in favour of the own face but longer fixations, see Chapter 8) but looks like those of Tong and Nakayama (1999, detection advantage for the self-face). These differences in results could again be explained by difference in the observer’s attentional set between our own visual search study and the two others. Indeed, as in Tong and Nakayama (1999)’ study, in the study of Pflugshaupt and al., spiders were the targets to be searched for. This example illustrates how it would be instructive to compare results obtained with different types of important stimuli in order to build more general theories about the way our visual system sorts out all the incoming visual inputs and extracts relevant information to allow us to perceive the world in an organised manner and behave in agreement with our current goals.

2. Perspectives

Throughout this general discussion, we evoked several hypotheses that would deserve further investigation. These hypotheses concerned the knowledge about the processing of the self-face or the use of the self-face as a tool of investigation of some cognitive processes. All these perspectives are summarized below.

A first extension of the present thesis could consist in examining other aspects (e.g. emotional aspects) of the representation of one's own face. On the one hand, as discussed above, it would be interesting to test whether the representation of one's own face include a typical facial expression and whether this expression is different or not from that of other personally known individuals. On the other hand, one could ask participants various questions about the way they perceive their own face (i.e. its relative attractiveness or distinctiveness) and how the same face is perceived by other familiar persons to examine whether the subjective representation of the self-face and other familiar faces is comparable. Furthermore, it could be interesting to assess the representation of the self-face in patients suffering of body dysmorphic disorder (BDD) and to compare this representation to that of participant that do not have such a disorder. This might help to build adequate treatment programs to correct the erroneous beliefs or representations of BDD patients. Indeed, patients with BDD are often particularly concerned with their facial appearance (see e.g. Veale, 2004). For instance, it has been shown that patients suffering from a BDD judged pictures of their own face less attractive than independent evaluators. In addition, BDD patients judged pictures of attractive persons as more attractive than control subjects (Buhlmann, Etcoff, & Wilhelm, in press).

A second important extension of the present work would be to use neuroimaging techniques during various visual attention tasks in which the participant's own face is presented irrelevantly for the task at hand. Indeed, such techniques would offer a mean to assess to which extent the self-face is processed by the brain in such situations, to relate these possible self-related brain activations to behavioural measurements (e.g. presence or absence of interference produced by the presentation of the self-face on the main task), and importantly to test whether the self-face is processed as a self-related stimulus (i.e., if it activates specific cerebral areas by comparison with another highly familiar face) or merely as a highly familiar stimulus (i.e., if the self-face and another familiar face activate similar cerebral areas and that differ from areas activated by the presentation of unfamiliar faces).

Finally, a third extension of the current work could concern the attentional deploying towards complex visual stimuli as investigated with eye movements recording. We showed that the self-face does not capture attention when its processing is not necessary to the task at hand. Studies using simple visual stimuli (e.g. flashes) have shown that the attentional set of the observer (Folk et al., 1992, 1994; but see Schreij et al., 2008) and the general context in which the stimulus appears (e.g. when its characteristics are unique, Pashler & Harris, 2001) are important factors in the determination of the attentional selection of these simple visual stimuli. Therefore, in order to test whether the same conclusion apply to complex visual stimuli, our eye movement study should be complemented by another study in which the target is defined by the identity and in which participants are instructed to search their own face or other faces. Moreover, in order to have a general characterization of the allocation of attention towards important stimuli, it seems crucial to assess whether results found with the self-face apply to other kinds of important stimuli (e.g. fear-related stimuli in anxious patients).

3. Conclusion

This thesis concerned the specificity of a highly distinctive self-referential stimulus: the self-face. First, we showed that the perceptual representation in memory of the self-face is similar to that of other familiar faces as regard with its precision. Second, we demonstrated that although one’s own face perceptual representation is not really special, the visual processing of the self-face is subtended by specific neural correlates. Apparently, the self-body is also processed via specialised pathways in the brain. In addition, some regions seem devoted to the abstract processing of one’s own physical appearance independently of the material presented. Third, we showed that one’s own face is not a particularly potent distractor by comparison with other familiar faces. It does not seem able to capture attention but rather benefits from a preferential allocation of attention by comparison with unfamiliar faces. In other words, its attentional processing is subject to various constraints (e.g. spatial localisation, available attentional resources) and attention seems necessary to process self-referential parts of a face. We discussed the idea that the presentation of the self-face can constitute a way to enhance chances of eliciting responses in non-communicative patients but that it is not the best way to study self-consciousness in normal adults when using only behavioural methods. In addition, because of its unique characteristics, the self-face can represent a useful tool of investigation of visual recognition and visual attention.

REFERENCES

Amsterdam, B.K. (1972). Mirror self-image reactions before age two. *Developmental Psychobiology, 5,* 297-305.

Anderson, J.R., & Gallup, G.G.Jr. (1997). Self-recognition in Saguinus? A critical essay. *Animal Behaviour, 54*, 1563-1567.

Anderson, J.R., & Gallup, G.G.Jr. (1999). Self-recognition in nonhuman primates: Past and future challenges. In Haug, M., & Whalen, R.E (Eds.), *Animal models of human emotion and cognition* (pp. 175-194). Washington, DC: American Psychological Association.

Antelme, R. (1957). *L'espèce humaine.* Paris: Gallimard.

Arnell, K.M., Shapiro, K.L., & Sorensen, R.E. (1999). Reduced repetition blindness for one's own name. *Visual Cognition, 6,* 609-635.

Asendorpf, J.B., & Baudonnière, P.M. (1993). Self-awareness and other-awareness: Mirror self-recognition and synchronic imitation among unfamiliar peers. *Developmental Psychology, 29*, 88-95.

Bard, K.A., Todd, B., Bernier, C., Love, J., & Leavens, D.A. (2006). Self-awareness in human and chimpanzee infants: What is measured and what is meant by the mirror-and-mark test? *Infancy, 9,* 185-213.

Beck, D. & Lavie, N. (2005). Look here but ignore what you see: Effects of distractors at fixation. *Journal of Experimental Psychology: Human Perception and Performance, 31,* 592-607.

Berlad, I., & Pratt, H. (1995). P300 in response to the subject's own name. *Electroencephalography and Clinical Neurophysiology, 96,* 472-474.

Berry, D.S., & McArthur, L.Z. (1986). Perceiving character in faces: The impact of age-related craniofacial changes on social perception. *Psychological Bulletin, 100,* 3-18.

Bertenthal, B.I., & Fischer, K.W. (1978). Development of self-recognition in the infant. *Developmental Psychology, 14*, 44-50.

Bologna, S.M., & Camp, C.J. (1997). Covert versus overt self-recognition in late stage Alzheimer's disease. *Journal of the International Neuropsychological Society, 3*, 195-198.

Bonner, L., Burton, A.M. & Bruce, V. (2003). Getting to know you: How we learn new faces. *Visual Cognition, 10,* 527-536.

Brady, N., Campbell, M., & Flaherty, M. (2004). My left brain and me: A dissociation in the perception of self and others. *Neuropsychologia, 42*, 1156-1161.

Brady, N., Campbell, M., & Flaherty, M. (2005). Perceptual asymmetries are preserved in memory for highly familiar faces of self and classmate. *Brain and Cognition, 58,* 334-342.

Brédart, S. (2003). Recognising the usual orientation of one's own face: The role of asymmetrically located details. *Perception, 32*, 805-811.

Brédart, S. (2004). Cross-modal facilitation is not specific to self-face recognition. *Consciousness & Cognition, 13,* 610-612.

Brédart, S., Delchambre, M., & Laureys, S. (2006). One's own face is hard to ignore. *The Quarterly Journal of Experimental Psychology, 59,* 46-52.

Brédart, S., & Devue, C. (2006). The accuracy of memory for faces of personally known individuals. *Perception, 35,* 101-106.

Brédart, S., & Young, A. (2004). Self-recognition in everyday life. *Cognitive Neuropsychiatry, 9,* 183-197.

Breen, N., Caine, D., & Coltheart, M. (2001). Mirrored-self misidentification: Two cases of focal onset dementia. *Neurocase, 7*, 239-254.

Broadbent, D.E. (1958). *Perception and Communication.* London: Pergamon Press.

Brooks, K.R., & Kemp, R.I. (2007). Sensitivity to feature displacement in familiar and unfamiliar faces: Beyond the internal/external feature distinction. *Perception, 36,* 1646-1659.

Brown, P., & Marsden, J.F. (2001). Cortical network resonance and motor activity in humans. *Neuroscientist, 7,* 518-527.

Bruce, V. (1988). *Recognizing Faces.* Hillsdale, N.J.: Lawrence Erlbaum Associates.

Bruce, V., Henderson, Z., Newman, C., & Burton, M. (2001). Matching identities of familiar and unfamiliar faces caught on CCTV images. *Journal of Experimental Psychology: Applied*, *7,* 207-218.

Bruce, V., & Young, A. (1998). *In the eye of the beholder: The science of face perception.* Oxford: Oxford University Press.

Buhlmann, U., Etcoff, N.L., & Wilhelm, S. (in press). Facial attractiveness ratings and perfectionism in body dysmorphic disorder and obsessive-compulsive disorder. *Journal of Anxiety Disorders.* doi:10.1016/j.janxdis.2007.05.004

Bundesen, C., Killingsbæk, S., Houmann, K. J., & Jensen, R. M. (1997). Is visual attention automatically attracted by one's own name? *Perception & Psychophysics, 59*, 714-720.

Buttle, H., & Raymond, J.E. (2003). High familiarity enhances visual change detection for face stimuli. *Perception & Psychophysics, 65,* 1296-1306.

Carmody, D.P., & Lewis, M. (2006). Brain activation when hearing one's own and others' names. *Brain Research, 1116,* 153-158.

Casey, S. & Newell, F.N. (2005). The role of short and long term familiarity on visual and haptic face recognition. *Experimental Brain Research, 166,* 583-591.

Chan, A.W.-Y., Peelen, M.V., & Downing, P.E. (2004). The effect of viewpoint on body representation in the extrastriate body area. *NeuroReport, 15,* 2407-2410.

Cherry, E.C. (1953). Experiments on the recognition of speech with one and two ears. *Journal of the Acoustical Society of America, 25,* 975-979.

Cole, J. (1999). *About face.* Cambridge, MA: MIT press.

Collins, J.K. (1981). Self-recognition of the body and its parts during late adolescence. *Journal of Youth and Adolescence, 10,* 243-254.

Courage, M.L., & Howe, M.L. (2002). From infant to child: The dynamics of cognitive change in the second year of life. *Psychological Bulletin, 128*, 250-277.

Craik, F.I.M., Moroz, T.M., Moscovitch, M., Stuss, D.T., Winocur, G., Tulving, E., & Kapur, S. (1999). In search of the self: A positron emission tomography study. *Psychological Science, 10*, 26-34.

Damasio, A.R. (1999). *The feeling of what happens: Body and emotion in the making of consciousness.* New York: Harcourt Brace.

Daprati, E., Franck, N., Georgieff, N., Proust, J., Pacherie, E., Dalery, J., & Jeannerod, M. (1997). Looking for the agent: An investigation into consciousness of action and self-consciousness in schizophrenic patients. *Cognition, 65,* 71-86.

D'Argembeau, A., Collette, F., Van der Linden, M., Laureys, S., Del Fiore, G., Degueldre, C., Luxen, A., & Salmon, E. (2005). Self-referential reflective activity and its relationship with rest: a PET study. *NeuroImage, 25,* 616-624.

Daury, N., Brooks, K., & Brédart, S. (submitted). Perceptual memory for familiar people's body shape.

David, E., Laloyaux, C., Devue, C., & Cleeremans, A. (2006). Change blindness to gradual changes in facial expressions. *Psychologica Belgica, 46,* 253-258.

Dawkins, M.S. (2006). Through animal eyes: What behaviour tells us. *Applied Animal Behaviour Science, 100,* 4-10.

de Ajuriaguerra, J., Strejilevitch, M., & Tissot, R. (1963). A propos de quelques conduites devant le miroir de sujets atteints de syndromes démentiels du grand âge. *Neuropsychologia, 1*, 59-73.

Delfour, F., & Marten, K. (2001). Mirror image processing in three marine mammal species: Killer whales (*Orcinus orca*), false killer whales (*Pseudorca crassidens*) and California sea lions (*Zalophus californianus*). *Behavioural Processes, 53,* 181-190.

Dennett, D.C. (1991). *Consciousness explained.* Boston: Little Brown.

Deutsch, J., & Deutsch, D. (1963). Attention: Some theoretical consideration. *Psychological Review*, *87,* 272-300.

de Veer, M.W., Gallup, G.G.Jr, Theall, L.A., van den Bos, R., & Povinelli, D.J. (2003). An 8-year longitudinal study of mirror self-recognition in chimpanzees (*Pan troglodytes*). *Neuropsychologia, 41,* 229-234.

Devue, C. (2004). *La reconnaissance de soi et de visages personnellement familiers: Détection de transformations faciales liées à l'âge.* Mémoire non publié, Université de Liège.

Devue, C., & Brédart, S. (in press). Attention to self-referential stimuli: Can I ignore my own face? *Acta Psychologica.*

Devue, C., Collette, F., Balteau, E., Degueldre, C., Luxen, A., Maquet, P., & Brédart, S. (2007). Here I am: The cortical correlates of visual self-recognition. *Brain Research, 1143,* 169-182.

Devue, C., Van der Stigchel, S., Brédart, S., & Theeuwes, J. (submitted). You do not find your own face faster; you just look at it longer.

de Waal, F.B.M., Dindo, M., Freeman, C.A., & Hall, M.J. (2005). The monkey in the mirror: Hardly a stranger. *Proceedings of the National Academy of Sciences of the United States of America, 102,* 11140-11147.

Di, H.B., Yu, S.M., Weng, X.C., Laureys, S., Yu, D., Li, J.Q., Qin, P.M., Zhu, Y.H., Zhang, S.Z., & Chen, Y.Z. (2007). Cerebral response to patient's own name in the vegetative and minimally conscious states. *Neurology, 68,* 895-899.

Diamond, J., & Bond, A. (1989). Note on the lasting responsiveness of a kea *Nestor notabilis* toward its mirror image. *Avicultural Magazine, 95,* 92-94.

Diamond, R., & Carey, S. (1986). Why faces, are and are not special: An effect of expertise. *Journal of Experimental Psychology: General, 115,* 107-117.

Downing, P.E., Chan, A.W.-Y., Peelen, M.V., Dodds, C.M., & Kanwisher, N. (2006). Domain specificity in visual cortex. *Cerebral Cortex,16,* 1453-1461.

Downing, P.E., Jiang, Y., Shuman, M., & Kanwisher, N. (2001). A cortical area selective for visual processing of the human body. *Science, 293*, 2470-2473.

Duval, S., & Wicklund, R.A. (1972). *A theory of objective self awareness.* New York: Academic Press.

Eger, E., Schweinberger, S.R., Dolan, R.J., & Henson, R.N. (2005). Familiarity enhances invariance of face representations in human ventral visual cortex: fMRI evidence. *NeuroImage, 26,* 1128-1139.

Ellis, H.D., Jones, D.M., & Mosdell, N. (1997). Intra- and inter-modal repetition priming of familiar faces and voices. *British Journal of Psychology, 88*, 143-156.

Ellis, H.D., & Lewis, M.B. (2001). Capgras delusion: A window on face recognition. *Trends in Cognitive Sciences, 5*, 149-156.

Ellis, H.D., Shepherd, J.W., & Davies, G.M. (1979). Identification of familiar and unfamiliar faces from the internal and the external features: Some implications for theories of face recognition. *Perception, 8,* 431-439.

Endo, N., Endo, M., Kirita, T., & Maruyama, K. (1992). The effects of expression on face recognition. *Tohoku Psychologia Folia, 51,* 37-44.

Epstein, R., Lanza, R.P., & Skinner, B.F. (1981). ‘‘Self-awareness’’ in the pigeon. *Science, 212,* 695-69.

Ewbank, M.P., Smith, W.A., Hancock, E.R., & Andrews, T.J. (2008). The M170 reflects a viewpoint-dependent representation for both familiar and unfamiliar faces. Cerebral Cortex, doi:10.1093/cercor/bhm060.

Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is "special" about face perception ? *Psychological Review, 105,* 482-498.

Farrer, C., Franck, N., Georgieff, N., Frith, C.D., Decety, J., & Jeannerod, M. (2003). Modulating the experience of agency: A positron emission tomography study. *NeuroImage, 18,* 324-333.

Farrer, C., & Frith, C.D. (2002). Experiencing oneself vs another person as being the cause of an action: The neural correlates of the experience of agency. *NeuroImage 15,* 596-603.

Farrer, C., Passingham, R.E., & Frith, C.D. (2002). A role for the ventral visual system in reporting movements. *NeuroImage, 15,* 587-595.

Feinberg, T.E., Eaton, L.A., Roane, D.M., & Giacino, J.T. (1999). Multiple Fregoli delusions after traumatic brain injury. *Cortex, 35,* 373-387.

Feinberg T.E., & Keenan, J.P. (2005). Where in the brain is the self? *Consciousness & Cognition, 14,* 661-678.

Fenigstein, A., Scheier, M.F., & Buss, A.H. (1975). Public and private self-consciousness: Assessment and theory. *Journal of Consulting and Clinical Psychology, 43,* 522-527.

Fink, G.R., Markowitsch, H.J., Reinkemeier, M., Bruckbauer, T., Kessler, J., & Heiss, W-D. (1996). Cerebral representation of one's own past: Neural networks involved in autobiographical memory. *Journal of Neuroscience, 16*, 4275-4282.

Fischler, I., Jin, Y.-S., Boaz, T.L., Perry, N.P.Jr., & Childers, D.G. (1987). Brain potentials related to seeing one's own name. *Brain and Language, 30,* 245-262.

Folk, C.L., Remington, R.W., & Johnston, J.C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 1030-1044.

Folk, C.L., Remington, R.W., & Wright, J.H. (1994). The structure of attentional control: contingent attentional capture by apparent motion, abrupt onset, and color. *Journal of Experimental Psychology. Human Perception and Performance, 20,* 317-329.

Folmer, R.L., & Yingling, C.D. (1997). Auditory P3 responses to name stimuli. *Brain and Language, 56,* 306-311.

Fossati, P., Hevenor, S.J., Graham, S.J., Grady, C., Keightley, M.L., Craik, F., & Mayberg, H. (2003). In search of the emotional self: An fMRI study using positive and negative emotional words. *American Journal of Psychiatry, 160,* 1938-1945.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in sub-clinical anxiety? *Journal of Experimental Psychology: General, 130,* 681-700.

Franck, N., Farrer, C., Georgieff, N., Marie-Cardine, M., Daléry, J., d'Amato, T., & Jeannerod, M. (2001). Defective recognition of one's own actions in patient with schizophrenia. *American Journal of Psychiatry, 158,* 454-459.

Gallagher, I. (2000). Philosophical conceptions of the self: Implications for cognitive sciences. *Trends in Cognitive Sciences, 4,* 14-21.

Gallegos, D., & Tranel, D. (2005). Positive facial affect facilitates the identification of famous faces. *Brain and Language, 93,* 338-348.

Gallup, G.G.Jr. (1968). Mirror-image stimulation. *Psychological Bulletin, 70,* 782-793.

Gallup, G.G.Jr. (1970). Chimpanzees: Self-recognition. *Science, 167,* 86-87.

Gallup, G.G.Jr. (1977). Absence of self-recognition in a monkey (*Macaca fascicularis*) following prolonged exposure to a mirror. *Developmental Psychobiology, 10,* 281-284.

Gallup, G.G.Jr. (1998). Self-awareness and the evolution of social intelligence. *Behavioural Processes, 42,* 239-247.

Gallup, G.G., Anderson, J.R., & Platek, S.M. (2003). Self-awareness, social intelligence and schizophrenia. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry* (pp. 147-165). Cambridge,UK: Cambridge University Press.

Gallup, G.G.Jr, Anderson, J.R., & Shillito, D.J. (2002). The mirror test. In Bekoff, M., Allen, C. & Burghardt, G.M (Eds.), *The cognitive animal: Empirical and theoretical perspectives on animal cognition* (pp. 325-333). Cambridge, MA, US: MIT Press.

Gallup, G.G.Jr., Povinelli, D.J., Suarez, S.D., Anderson, J.R., Lethmate, J., & Menzel, E.W. (1995). Further reflections on self-recognition in primates. *Animal Behaviour, 50,* 1525-1532.

Ganel, T., & Goshen-Gottstein, Y. (2004). Effects of familiarity on the perceptual integrality of the identity and expression of faces: The parallel-route hypothesis revisited. *Journal of Experimental Psychology: Human Perception and Performance, 30,* 583-597.

Garsoffky, B., Schwan, S., & Hesse, F.W. (2002). Viewpoint dependency in the recognition of dynamic scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 1035-1050.

Gauthier, I., Tarr, M.J., Moylan, J., Skudlarski, P., Gore, J.C., & Anderson, A.W. (2000). The fusiform "face area" is part of a network that processes faces at the individual level. *Journal of Cognitive Neuroscience, 13,* 495-504.

Gauthier, I., Williams, P., Tarr, M.J., & Tanaka, J. (1998). Training "Greebles" experts: A framework for studying expert object recognition processes. *Vision Research, 38,* 2401-2428.

Ge, L., Luo, J., Nishimura, M., & Lee, K. (2003). The lasting impression of Chairman Mao: Hyperfidelity of familiar-face memory, *Perception, 32,* 601-614.

Gillihan, S.J., & Farah, M.J. (2005). Is self special? A critical review of evidence from experimental psychology and cognitive neuroscience. *Psychological Bulletin, 131,* 76-97.

Glila, T., & Dehaene-Lambertz, G. (2005). Structural encoding of body and face in human infants and adults. *Journal of Cognitive Neuroscience, 17,* 1328-1340.

Gouin-Decarie, T., Pouliot, T., & Poulin-Dubois, D. (1983). Image spéculaire et genèse de la reconnaissance de soi: Une analyse hiérarchique. *Enfance, 1,* 99-115.

Gray, H. M., Ambady, N., Lowenthal, W. T., & Deldin, P. (2004). P300 as an index of attention to self-relevant stimuli. *Journal of Experimental Social Psychology, 40,* 216-224.

Greenfield, S.A., & Collins, T.F.T. (2005). A neuroscientific approach to consciousness. *Progress in Brain Research, 150,* 11-23.

Gregory, R. (2001). Seeing oneself. *Perception, 30,* 903-904.

Grewal, R.P. (1994). Self-recognition in dementia of the Alzheimer type. *Perceptual and Motor Skills, 79*, 1009-1010.

Grill-Spector, K., Henson, R., & Martin, A. (2006). Repetition and the brain: neural models of stimulus-specific effects. *Trends in Cognitive Sciences, 10,* 14-23.

Grill-Spector, K., Knouf, N., & Kanwisher, N. (2004). The fusiform face area subserves face perception, not generic within-category identification. *Nature Neuroscience, 7,* 555-562.

Gronau, N., Cohen, A., & Ben-Shakhar, G. (2003). Dissociations of personally-significant and task-relevant distractors inside and outside the focus of attention: A combined behavioural and psychophysiological study. *Journal of Experimental Psychology: General*, *132,* 512-529.

Gross, J., Harmon, M.E., Myers, R.A., Evans, R.L., Kay, N.R., Rodriguez-Charbonier, S., & Herzog, T.R. (2004). Recognition of self among persons with dementia: Pictures versus names as environmental supports. *Environment and Behavior, 36,* 424-454.

Gusnard, D.A. (2005). Being a self: Considerations from functional imaging. *Consciousness & Cognition, 14,* 679-697.

Harris, C. R., & Pashler, H.E. (2004). Attention and the processing of emotional words and names: Not so special after all. *Psychological Science*, *15,* 171-178.

Harris, C. R., Pashler, H.E., & Coburn, N. (2004). Moray revisited: High-priority affective stimuli and visual search. *The Quarterly Journal of Experimental Psychology, 57*, 1-31.

Harrison, B.J., Yücel, M., Pujol, J., & Pantelis, C. (2007). Task-induced deactivation of midline cortical regions in schizophrenia assessed with fMRI. *Schizophrenia Research, 91,* 82-86.

Hauser, M.D., Kralik, J., Botto-Mahan, C., Garrett, M., & Oser, J. (1995). Self-recognition in primates: Phylogeny and the salience of species-typical traits. *Proceedings of the National Academy of Sciences of the United States of America, 92,* 10 811-10 814.

Haxby, J., Hoffman, E., & Gobbini, M.I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences, 4,* 223-233.

Heatherton, T.F., Macrae, C.N., & Kelley, W.M. (2004). What the social brain sciences can tell us about the self. *Current Directions in Psychological Science, 13,* 190-193.

Hehman, J.A., German, T., & Klein, S.B. (2005). Impaired self-recognition from recent photographs in a case of late-stage Alzheimer's Disease. *Social Cognition, 23,* 118-123.

Henriet, K., Haouzir, S., & Petit, M. (2008). L'illusion des sosies de Capgras: Une interprétation délirante d'un trouble spécifique de la reconnaissance affective des visages. Revue de la littérature et proposition d'un modèle séquentiel. *Annales Médico Psychologiques, 166,* 147-156.

Herschkowitz, N. (2000). Neurological bases of behavioral development in infancy. *Brain & Development, 22*, 411-416.

Heyes, C.M. (1994). Reflections on self-recognition in primates. *Animal Behaviour, 47,* 909-919.

Hirata, S. (2007). A note on the responses of chimpanzees (*Pan troglodytes*) to live self-images on television monitors. *Behavioural Processes*, *75,* 85-90.

Holeckova, I., Fischer, C., Giard, M.-H., Delpuech, C., & Morlet, D. (2006). Brain responses to a subject's own name uttered by a familiar voice. *Brain Research, 1082,* 142-152.

Irani, F., Platek, S.M., Panyavin, I.S., Calkins, M.E., Kohler, C., Siegel, S.J., Schachter, M., Gur, R.E., & Gur, R.C. (2006). Self-face recognition and theory of mind in patients with schizophrenia and first-degree relatives. *Schizophrenia Research, 88,* 151-160.

Jeannerod, M. (2003). Les troubles de la reconnaissance de soi: Une approche neuropsychologique des symptômes positifs de la schizophrénie. *Medecine Sciences, 19*, 621-624.

Jeannerod, M., Farrer, C., Franck, N., Fourneret, P., Posada, A., Daprati, E., & Georgieff, N. (2003). Action recognition in normal and schizophrenic subjects. In Kircher, T. & David, A. S. (Eds.), *The Self in Neuroscience and Psychiatry* (pp. 380-406). Cambridge, UK: Cambridge University Press.

Johnson, D.B. (1983). Self-recognition in infants. *Infant Behavior & Development, 6*, 211-222.

Johnson, S.C., Baxter, L.C., Wilder, L.S., Pipe, J.G., Heiserman, J.E., & Prigatano, G.P. (2002). Neural correlates of self-reflection. *Brain, 125,* 1808-1814.

Jokisch, D., Daum, I., & Troje, N.F. (2006). Self recognition versus recognition of others by biological motion: Viewpoint-dependent effects. *Perception,35,* 911-920.

Kampf, M., Nachson, I., & Babkoff, H. (2002). A serial test of the laterality of familiar face recognition. *Brain and Cognition, 50,* 35-50.

Kanwisher, N., McDermott, J., & Chun, M.M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience,17,* 4302-4311.

Kaufmann, J.M., & Schweinberger, S.R. (2004). Expression influences the recognition of familiar faces. *Perception, 33,* 399-408.

Kawahara, J., & Yamada, Y. (2004). Does one's name attract visual attention? *Visual Cognition*, *11,* 997-1017.

Keenan, J.P., Freund, S., Hamilton, R.H., Ganis, G., & Pascual-Leone, A. (2000). Hand response differences in a self-face identification task. *Neuropsychologia, 38*, 1047-1053.

Keenan, J.P., Gallup, G.G.Jr., & Falk, D. (2003). *The face in the mirror: The search for the origin of consciousness.* New York: Ecco.

Keenan, J.P., Ganis, G., Freund, S., & Pascual-Leone, A. (2000). Self-face identification is increased with left hand responses. *Laterality, 5*, 259-268.

Keenan, J.P., McCutcheon, B., Freund, S., Gallup, G.G.Jr., Sanders, G., & Pascual-Leone, A. (1999). Left hand advantage in a self-face recognition task. *Neuropsychologia, 37*, 1421-1425.

Keenan, J.P., Nelson, A., O'Connor, M., & Pascual-Leone, A. (2001). Self-recognition and the right hemisphere. *Nature, 409*, 305.

Keenan, J.P., Rubio, J., Racioppi, C., Johnson, A. & Barnacz, A. (2005). The right hemisphere and the dark side of consciousness. *Cortex, 41,* 695-704.

Keenan, J.P., Wheeler, M., & Ewers, M. (2003b). The neural correlates of self-awareness and self-recognition. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry* (pp. 166-179). Cambridge, UK: Cambridge University Press.

Keenan, J.P., Wheeler, M.A., Gallup, G.G.Jr., & Pascual-Leone, A. (2000). Self-recognition and the right prefrontal cortex. *Trends in Cognitive Sciences, 4*, 338-344.

Keenan, J.P., Wheeler, M.A., Platek, S.M., Lardi, G., & Lassonde, M. (2003). Self-face processing in a callosotomy patient. *European Journal of Neuroscience, 18*, 2391-2395.

Kelley, W.M., Macrae, C.N., Wyland, C.L., Caglar, S., Inati, S., & Heatherton, T.F. (2002). Finding the Self? An event-related fMRI study. *Journal of Cognitive Neuroscience, 14,* 785-794.

Keyes, H., & Brady, N. (2007). My face or yours? Early and late ERP correlates of self-face recognition*. Perception, 36 ECVP Abstract Supplement,* 149.

Kircher, T.T.J., Brammer, M., Bullmore, E.T., Simmons, A., Bartels, M., & David, A.S. (2002). The neural correlates of intentional and incidental self processing. *Neuropsychologia, 40,* 683-692.

Kircher, T.T.J., & David, A.S. (2003). Self consciousness: An integrative approach from philosophy, psychopathology and the neurosciences. In Kircher, T. & David, A. S. (Eds.), *The Self in Neuroscience and Psychiatry* (pp. 445-474). Cambridge, UK: Cambridge University Press.

Kircher, T.T.J., & Leube, D.T. (2003). Self-consciousness, self-agency, and schizophrenia. *Consciousness & Cognition, 12,* 656-669.

Kircher, T.T.J., Seiferth, N.Y., Plewnia, C., Baar, S., & Schwabe, R. (2007). Self-face recognition in schizophrenia. *Schizophrenia Research, 94,* 264-272.

Kircher, T.T.J., Senior, C., Phillips, M.L., Benson, P.J., Bullmore, E.T., Brammer, M., Simmons, A., Williams, S.C.R., Bartels, M., & David, A.S. (2000). Towards a functional neuroanatomy of self processing: Effects of faces and words. *Cognitive Brain Research, 10*, 133-144.

Kircher, T.T.J., Senior, C., Phillips, M.L., Rabe-Hesketh, S., Benson, P.J., Bullmore, E.T., Brammer, M., Simmons, A., Bartels, M., & David, A.S. (2001). Recognizing one's own face. *Cognition, 78*, B1-B15.

Kirita, T., & Endo, M. (2001). Facial representations contain the information concerning expressions: Evidence from priming experiments. *Tohoku Psychologia Folia,60,* 45-60.

Kitchen, A., Denton, D., & Brent, L. (1996). Self-recognition and abstraction abilities in the common chimpanzee studied with distorting mirrors. *Proceedings of the National Academy of Sciences of the United States of America, 93,* 7405-7408.

Kjaer, T.W., Nowak, M., & Lou, H.C. (2002). Reflective self-awareness and conscious states: PET evidence for a common midline parietofrontal core. *NeuroImage, 17,* 1080-1086.

Koch, C. (2004). *The quest for consciousness: A neurobiological approach.* Englewood: Roberts & Company Publishers.

Kriegel, U. (2007). A cross-order integration hypothesis for the neural correlate of consciousness. *Consciousness & Cognition, 16,* 897-912.

Kuiper, N.A. (1982). Processing personal information about well-known others and the self: The use of efficient cognitive schemata. *Canadian Journal of Behavioral Science, 14,* 1-12.

Kuiper, N., & Rogers, T (1979) Encoding of personal information: Self-other differences. *Journal of Personality and Social Psychology, 37,* 499-514.

Kurosaki, M., Shirao, N., Yamashita, H., Okamoto, Y., & Yamawaki, S. (2006). Distorted images of one’s own body activates the prefrontal cortex and limbic/paralimbic system in young women: A functional magnetic resonance imaging study. *Biological Psychiatry, 59,* 380-386.

Laarni, J., Koljonen, M., Kuistio, A.M., Kyröläinen, S., Lempiäinen, J., & Lepistö, T. (2000). Images of a familiar face do not capture attention under conditions of inattention. *Perceptual and Motor Skills*, *90,* 1216-1218.

Lachter, J., Forster, K.I., & Ruthruff, E. (2004). Forty-five years after Broadbent (1958): Still no identification without attention. *Psychological Review, 111,* 880-913.

Laeng, B., & Rouw, R. (2001). Canonical views of faces and the cerebral hemispheres. *Laterality, 6*, 193-224.

Laureys, S., Perrin, F., & Brédart, S. (2007). Self-consciousness in non-communicative patients. *Consciousness & Cognition*, *16,* 722-741.

Ledbetter, D.H., & Basen, J.A. (1982). Failure to demonstrate self-recognition in gorillas. *American Journal of Primatology, 2,* 307-310.

Lee, J., Kwon, J.S., Shin, Y.-W., Lee, K.J., & Park, S. (2007). Visual self-recognition in patients with schizophrenia. *Schizophrenia Research*, *94,* 215-220.

Legerstee, M., Anderson, D., & Schaffer, A. (1998). Five- and eight-month-old infants recognize their faces and voices as familiar and social stimuli. *Child Development, 69*, 37-50.

Legrand, D. (2003). How not to find the neural signature of self-consciousness. *Consciousness & Cognition, 12,* 544-546.

Levi, P. (1987). *Si c’est un homme.* Paris: Julliard.

Lewis, M., & Brooks-Gunn, J. (1979). *Social Cognition and Aquisition of Self.* New York: Plenum Press.

Lin, A.C., Bard, K.A., & Anderson, J.R. (1992). Development of self-recognition in chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology, 106,* 120-127.

Lindner, A., Their, P., Kircher, T.T.J., Haarmeier, T., & Leube, D.T. (2005). Disorders of agency in schizophrenia correlate with an inability to compensate fort he sensory consequences of actions. *Current Biology, 15,* 1119-1124.

Mack, A., Pappas, Z., Silverman, M., & Gay, R. (2002). What we see: Inattention and the capture of attention by meaning. *Consciousness & Cognition, 11,* 488-506.

Mack, A., & Rock, I. (1998). *Inattentional blindness.* Cambridge, MA: MIT Press.

Mead, G.H. (1934). *Mind, self, and society.* Chicago: University of Chicago Press.

Megreya, A.M., & Burton, A.M. (2006). Unfamiliar faces are not faces: Evidence from a matching task. *Memory & Cognition, 34,* 865-876.

Metzinger, T. (2003). *Being no one.* Cambridge, MA: MIT Press.

Miller, B.L., Seeley, W.W., Mychack, P., Rosen, H.J., Mena, I., & Boone, K. (2001). Neuroanatomy of the self: Evidence from patients with frontotemporal dementia. *Neurology, 57,* 817-821.

Mita, T.H., Dermer, M., & Knight, J. (1977). Reversed facial images and the mere-exposure hypothesis. *Journal of Personality and Social Psychology, 35,* 597-601.

Mitchell, R.W. (1993). Mental models of mirror-self-recognition: Two theories. *New Ideas in Psychology, 11,* 295-325.

Mitchell, R.W. (1997). Kinesthetic-visual matching and the self-concept as explanations of mirror-self-recognition. *Journal for the Theory of Social Behaviour, 27,* 17-39.

Miyakoshi, M., Nomura, M., & Ohira, H. (2007). An ERP study on self-relevant object recognition. *Brain and Cognition, 63,* 182-189.

Miyazaki, M., & Hiraki, K. (2006). Delayed intermodal contingency affects young children's recognition of their current self. *Child Development, 77,* 736-750.

Molchan, S.E., Martinez, R.A., Lawlor, B.A., Grafman, J.H., & Sunderland, T. (1990). Reflections of the self: Atypical misidentification and delusional syndromes in two patients with Alzheimer's disease. *British Journal of Psychiatry, 157,* 605-608.

Montepare, J.M., & Zebrowitz, L.A. (1998). Person perception comes of age: The salience and significance of age in social judgments. *Advances in Experimental Social Psychology, 30,* 93-161.

Moody, E.J., McIntosh, D.N., Mann, L.J., & Weisser, K.R. (2007). More than the mimicry? The influence of emotion on rapid facial reactions to faces. *Emotion, 7,* 447-457.

Moray, N. (1959). Attention and dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology, 11,* 56-60.

Morin, A. (2002). Right hemispheric self-awareness: A critical assessment. *Consciousness & Cognition, 11*, 396-401.

Morin, A. (2003). The self and its brain: A critical examination of “The Face in the Mirror”. *Science & Consciousness Review, 1,* 1-10.

Morin, A. (2006). Levels of consciousness and self-awareness: A comparison and integration of various neurocognitive views. *Consciousness & Cognition, 15,* 358-371.

Morin, A. (2007). Self-awareness and the left hemisphere: The dark side of selectively reviewing the literature. *Cortex, 43,* 1068-1073.

Morton, D.B. (2000). Self-consciousness and animal suffering. *The Biologist, 47,* 77-80.

Nagaratnam, N., Irving, J., & Kalouche, H. (2003). Misidentification in patients with dementia. *Archives of Gerontology and Geriatrics, 37,* 195-202.

Neisser, U. (1997). The roots of self-knowledge: Perceiving self, it, and thou. In J.G. Snodgrass & R.L. Thompson (Eds.), *The self across psychology: Self-recognition, self-awareness, and the self-concept* (pp. 18-33). New York: New York Academy of Sciences.

Newen, A., & Vogeley, K. (2003). Self-representation: Searching for a neural signature of self-consciousness. *Consciousness & Cognition, 12,* 529-543.

Nielsen, M., Dissanayake, C., & Kashima, Y. (2003). A longitudinal investigation of self-other discrimination and the emergence of mirror self-recognition. *Infant Behavior & Development, 26*, 213-226.

Ninomiya, H., Onitsuka, T., Chen, C.H., Sato, E., & Tashiro, N. (1998). P300 in response to the subject's own face. *Psychiatry and Clinical Neurosciences, 52*, 519-522.

Northoff, G., & Bermpohl, F. (2004). Cortical midline structures and the self. *Trends in Cognitive Sciences, 8*, 102-107.

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain: A meta-analysis of imaging studies on the self. *NeuroImage, 31,* 440-457.

O'Donnell, C., & Bruce, V. (2001). Familiarisation with faces selectively enhances sensitivity to changes made to the eyes. *Perception, 30,* 755-764.

Palermo, R., & Rhodes, G. (2003). Change detection in the flicker paradigm: Do faces have an advantage? *Visual Cognition*, *10,* 683-713.

Papageorgiou, C., Lykouras, L., Ventouras, E., Uzunoglu, N., & Christodoulou, G.N. (2002). Abnormal P300 in a case of delusional misidentification with coinciding Capgras and Frégoli symptoms. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 26,* 805- 810.

Pashler, H., & Harris, C. (2001). Spontaneous allocation of visual attention: Dominant role of uniqueness. *Psychonomic Bulletin and Review, 8,* 747-752.

Pashler, H., & Johnston, J. C. (1998). Attentional limitations in dual-task performance. In Pashler, H. (Ed.), *Attention* (pp. 155-189). Hove, UK: Psychology Press.

Paysant, J., Beis, J.M., Le Chapelain, L., & André, J.M. (2004). Mirror asomatognosia in right lesions stroke victims. *Neuropsychologia, 42,* 920-925.

Peelen, M.V., & Downing, P.E. (2005). Selectivity for human body in the fusiform gyrus. *Journal of Neurophysiology, 93*, 603-608.

Perrett, D.I., Smith, P.A.J., Potter, D.D., Mistlin, A.S., Head, A.S., Milner, A.D., & Jeeves, M.A. (1984). Neurons responsive to faces in the temporal cortex: Studies of functional organization, sensitivity to identity and relation to perception. *Human Neurobiology*, *3,* 197-208.

Perrin, F., Garcia-Larrea, L., Mauquiere, F., & Bastuji, H. (1999). A differential brain response to the subject's own name persists during sleep. *Clinical Neurophysiology, 110,* 2153-2164.

Perrin, F., Maquet, P., Peigneux, P., Ruby, P., Degueldre, C., Balteau, E., Del Fiore, G., Moonen, G., Luxen, A., & Laureys, S. (2005). Neural mechanisms involved in the detection of our first name: A combined ERPs and PET study. *Neuropsychologia, 43,* 12-19.

Perrin, F., Schnakers, C., Schabus, M., Degueldre, C., Goldman, S., Brédart, S., Faymonville, M.-E., Lamy, M., Moonen, G., Luxen, A., Maquet, P., & Laureys, S. (2006). Brain response to one's own name in vegetative state, minimally conscious state, and locked-in syndrome. *Archives of Neurology, 63,* 562-569.

Platek, S.M., & Gallup, G.G.Jr. (2002). Self-face recognition is affected by schizotypal personality traits. *Schizophrenia Research, 57*, 81-85.

Platek, S.M., Keenan, J.P., Gallup, G.G.Jr., & Mohamed, F.B. (2004). Where am I? The neurological correlates of self and other. *Cognitive Brain Research, 19,* 114-122.

Platek, S.M., Keenan, J.P., & Mohamed, F.B., (2005). Sex differences in the neural correlates of child facial resemblance: an eventrelated fMRI study. *NeuroImage 25,* 1336-1344.

Platek, S.M., Loughead, J.W., Gur, R.C., Busch, S., Ruparel, K., Phend, N., Panyavin, I.S., & Langleben, D.D. (2006). Neural substrates for functionally discriminating self-face from personally familiar faces. *Human Brain Mapping, 27,* 91-98.

Platek, S.M., Thomson, J.W., & Gallup, G.G.Jr. (2004). Cross-modal self-recognition: The role of visual, auditory, and olfactory primes. *Consciousness & Cognition, 13*, 197-210.

Plotnik, J.M., de Waal, F.B.M., & Reiss, D. (2006). Self-recognition in an Asian elephant. *Proceedings of the National Academy of Sciences of the United States of America, 103,* 17053-17057.

Pflugshaupt, T., Mosimann, U.P., von Wartburg, R., Schmitt, W., Nyffeler, T., & Müri, R.M. (2005). Hypervigilance-avoidance pattern in spider phobia. *Journal of Anxiety Disorders, 19,* 105-116.

Pourtois, G., Schwartz, S., Seghier, M.L., Lazeyras, F., & Vuilleumier, P. (2005). View-independent coding of face identity in frontal and temporal cortices is modulated by familiarity: An event-related fMRI study. *NeuroImage, 24,* 1214-1224.

Povinelli, D.J. (1989). Failure to find self-recognition in Asian elephants (*Elephas maximus*) in contrast to their use of mirror cues to discover hidden food. *Journal of Comparative Psychology, 103,* 122-131.

Povinelli, D.J., Landau, K.R., & Perilloux, H.K. (1996). Self-recognition in young children using delayed versus live feedback: Evidence for a developmental asynchrony. *Child Development, 67,* 1540-1554.

Povinelli, D.J., Rulf, A.B., Landau, K.R., & Bierschwale, D.T. (1993). Self-recognition in chimpanzees (*Pan troglodytes*): distribution, ontogeny, and patterns of emergence. *Journal of Comparative Psychology,107,* 347-72.

Povinelli, D.J., & Simon, B.B. (1998). Young children's understanding of briefly versus extremely delayed images of self: Emergence of the autobiographical stance. *Developmental Psychology, 34,* 188-194.

Puce, A., Allison, T., Asgari, M., Gore, J., & McCarthy, G. (1996). Differential sensitivity of human visual cortex to faces, letterstrings, and textures: a functional magnetic resonance imaging study. *Journal of Neuroscience, 16,* 5205-5215.

Reiss, D., & Marino, L. (2001). Mirror self-recognition in the bottlenose dolphin: A case of cognitive convergence. *Proceedings of the National Academy of Sciences of the United States of America, 98,* 5937-5942.

Rhodes, G. (1986). Memory for lateral asymmetries in well-known faces: Evidence for configural information in memory representations of faces. *Memory & Cognition, 14*, 209-219.

Ro, T., Russell, C., & Lavie, N. (2001). Changing faces: A detection advantage in the flicker paradigm. *Psychological Science*, *12*, 94-99.

Rochat, P. (2003). Five levels of self-awareness as they unfold early in life. *Consciousness & Cognition, 12,* 717-731.

Rochat, P., & Striano, T. (2002). Who's in the mirror? Self-other discrimination in specular images by four- and nine-month-old infants. *Child Development, 73*, 35-46.

Rochat, P., & Striano, T. (2000). Perceived self in infancy. *Infant Behavior & Development, 23*, 513-530.

Rooney, B., Brady, N., & Benson, C. (2007). Are the neural mechanisms that underlie self-face and other-face recognition shared or separate? An adaptation study. *Perception, 36 ECVP Abstract Supplement,* 152.

Rossion, B., Schiltz, C., & Crommelinck, M. (2003). The functionally defined right occipital and fusiform "face areas" discriminate novel from visually familiar faces. *NeuroImage, 19,* 877-883.

Ruby, P., & Decety, J. (2001). Effect of subjective perspective taking during simulation of action: A PET investigation of agency. *Nature Neuroscience, 4,* 546-550.

Salgado-Pineda, P., Caclin, A., Baeza, I., Junqué, C., Bernardo, M., Blin, O., & Fonlupt, P. (2007). Schizophrenia and frontal cortex: Where does it fail? *Schizophrenia Research, 91,* 73-81.

Sapara, A., Cooke, M., Fannon, D., Francis, A., Buchanan, R.W., Anilkumar, A.P.P., Barkataki, I., Aasen, I., Kuipers, E., & Kumari, V. (2007). Prefrontal cortex and insight in schizophrenia: A volumetric MRI study. *Schizophrenia Research, 89,* 22-34.

Saxe, R., Jamal, N., & Powell, L. (2006). My body or yours? The effect of visual perspective on cortical body representations. *Cerebral Cortex, 16,* 178-182.

Schilhab, T.S.S. (2004). What mirror self-recognition in nonhumans can tell us about aspects of self. *Biology and Philosophy, 19,* 111-126.

Schneider, W., & Shiffrin, R.M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review, 84,* 1-66.

Schooler, J.W. (2002). Re-representing consciousness: Dissociations between experience and meta-consciousness. *Trends in Cognitive Sciences, 6,* 339-344.

Schreij, D., Owens, C., & Theeuwes, J. (2008). Abrupt onsets capture attention independent of top-down control settings. *Perception & Psychophysics, 70,* 208-218.

Schwarzlose, R.F., Baker, C.I., & Kanwisher, N. (2005). Separate face and body selectivity on the fusiform gyrus. *Journal of Neuroscience, 25,* 11055-11059.

Seger, C.A., Stone, M., & Keenan, J.P. (2004). Cortical activations during judgments about the self and an other person. *Neuropsychologia, 42,* 1168-1177.

Shapiro, K.L, Caldwell, J., & Sorensen, R.E. (1997). Personal names and the attentional blink: A visual "cocktail party" effect. *Journal of Experimental Psychology: Human Perception and Performance*, *23,* 504-514.

Shelley-Tremblay, J., & Mack, A. (1999). Metacontrast masking and attention. *Psychological Science, 10,* 508-515.

Shiffrin, R.M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127-190.

Simons, D.J., & Chabris, C.F. (1999). Gorillas in our midst: Sustained inattentional blindness for dynamic events. *Perception, 28,* 1059-1074.

Singh, D. (1995). Female judgment of male attractiveness and desirability for relationships: Role of waist-to-hip ratio and financial status. *Journal of Personality and Social Psychology, 69,* 1089-1101.

Smith, E.E., & Kosslyn, S.M. (2007). *Cognitive Psychology: Mind and Brain.* Upper Saddle River, NJ: Prentice Hall.

Smith, C.U.M. (1998). Descartes' pineal neuropsychology. *Brain and Cognition, 36,* 57-72.

Solso, R.L, Maclin, M.K & Maclin, O.H (2005). *Cognitive Psychology* (7th ed.). Boston: Pearson Education.

Sperry, R.W., Zaidel, E., & Zaidel, D. (1979). Self recognition and social awareness in the deconnected minor hemisphere. *Neuropsychologia, 17*, 153-166.

Spiridon, M., Fischl, B., & Kanwisher, N. (2006). Location and spatial profile of category-specific regions in human extrastriate cortex. *Human Brain Mapping, 27,* 77-89.

Sternberg, R.J. (2006). *Cognitive Psychology* (4th ed.). Belmont, CA: Thomson Wadsworth.

Suddendorf, T. (1999). Children's understanding of the relation between delayed video representation and current reality: A test for self-awareness? *Journal of Experimental Child Psychology, 72,* 157-176.

Suddendorf, T., Simcock, G., & Nielsen, M. (2007). Visual self-recognition in mirrors and live videos: Evidence for a developmental asynchrony. *Cognitive Development, 22,* 185-196.

Sugiura, M., Kawashima, R., Nakamura, K., Okada, K., Kato, T., Nakamura, A., Hatano, K., Itoh, K., Kojima, S., & Fukuda, H. (2000). Passive and active recognition of one's own face. *NeuroImage, 11*, 36-48.

Sugiura, M., Sassa, Y., Jeong, H., Miura, N., Akitsuki, Y., Horie, K., Sato, S., & Kawashima, R. (2006). Multiple brain networs for visual self-recognition with different sensitivity for motion and body part. *NeuroImage, 32,* 1905-1917.

Sugiura, M., Watanabe, J., Maeda, Y., Matsue, Y., Fukuda, H., & Kawashima, R. (2005). Cortical mechanisms of visual self-recognition. *NeuroImage, 24,* 143-149.

Sui, J., Zhu, Y., & Han, S. (2006). Self-face recognition in attended and unattended conditions: An event-related brain potential study. *NeuroReport, 17,* 423-427.

Svendsen, G.E., & Armitage, K.B. (1973). Mirror-image stimulation applied to field behavioral studies. *Ecology, 54,* 623-627.

Swartz, K.B., & Evans, S. (1991). Not all chimpanzees (*Pan troglodytes*) show self-recognition. *Primates, 32,* 483-496.

Swartz, K.B., & Evans, S. (1994). Cognitive and social factors in chimpanzee and gorilla mirror behavior and self-recognition. In S.T. Parker, R.W. Mitchell, & M.L. Boccia (Eds.), *Self-awareness in animals and humans: Developmental perspectives* (pp. 189-206). New York: Cambridge University Press.

Symons, C.S., & Johnson, B.T. (1997). The self-reference effect in memory: A meta-analysis. *Psychological Bulletin, 121,* 371-394.

Tanaka, J.W., Curran, T., Porterfield, A.L., & Collins, D. (2006). Activation of preexisting and acquired face representations: The N250 event-related potential as an index of face familiarity. *Journal of Cognitive Neuroscience, 18,* 1488-1497.

Tarr, M.J., & Cheng, Y.D. (2003). Learning to see faces and objects. *Trends in Cognitive Sciences, 7,* 23-30.

Tarr, M.J., & Gauthier, I. (2000). FFA: A flexible fusiform area for subordinate-level visual processing automatized by expertise. *Nature Neuroscience 3,* 764-769.

Tarr, M.J., & Pinker, S. (1990). When does human object recognition use a viewer-centred reference frame? *Psychological Science, 1,* 253-256.

Theeuwes, J., & Van der Stigchel, S. (2006). Faces capture attention: Evidence from inhibition of return. *Visual Cognition*, *13,* 657-665.

Théoret, H., Kobayashi, M., Merabet, L., Wagner, T., Tormos, J.M., & Pascual-Leone, A. (2004). Modulation of right motor cortex excitability without awareness following presentation of masked self-images. *Cognitive Brain Research, 20*, 54-57.

Thompson, P. (2002). Eyes wide apart: Overestimating interpupillary distance. *Perception, 31*, 651-656.

Tong, F., & Nakayama, K. (1999). Robust representations for faces: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 1016-1035.

Traub, A.C., & Orbach, J. (1964). Psychophysical studies of body-image. *Archives of General Psychiatry, 11,* 53-66.

Treisman, A. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology, 12,* 242–248.

Treisman, A., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12,* 97-136.

Troje, N., & Kersten, D. (1999). Viewpoint-dependent recognition of familiar faces. *Perception, 28*, 483-487.

Turk, D.J., Heatherton, T.F., Kelley, W.M., Funnell, M.G., Gazzaniga, M.S., & Macrae, C.N. (2002). Mike or me? Self-recognition in a split-brain patient. *Nature Neuroscience, 5*, 841-842.

Uddin, L.Q., Kaplan, J.T., Molnar-Szakacs, I., Zaidel, E., & Iacoboni, M. (2005). Self-face recognition activates a frontoparietal “mirror” network in the right hemisphere: An event-related fMRI study. *NeuroImage, 25*, 926-935.

Uddin, L.Q., Molnar-Szakacs, I., Zaidel, E., & Iacobini, M. (2006). rTMS to the right inferior parietal lobule disrupts self–other discrimination. *Social Cognitive and Affective Neuroscience, 1,* 65-71.

Uddin, L.Q., Rayman, J., & Zaidel, E. (2005). Split-brain reveals separate but equal self-recognition in the two cerebral hemispheres. *Consciousness & Cognition, 14,* 633-640.

Underwood, G., Templeman, E., Lamming, L., & Foulsham, T. (in press). Is attention necessary for object identification? Evidence from eye movements during the inspection of real-world scenes. *Consciousness & Cognition,* doi:10.106/j.concog.2006.11.008

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology, 79,* 471-491.

Vanhaudenhuyse, A., Schnakers, C., Brédart, S., & Laureys, S. (2008). Assessment of visual pursuit in post-comatose states: Use a mirror. *Journal of Neurology, Neurosurgery, & Psychiatry, 79,* 223.

Veale, D. (2004). Advances in a cognitive behavioural model of body dysmorphic disorder. *Body Image, 1,* 113-125.

Vogeley, K. (2003). Schizophrenia as disturbance of the self-concept. In Kircher, T. & David, A. S. (Eds.), *The Self in Neuroscience and Psychiatry* (pp. 361-379). Cambridge, UK: Cambridge University Press.

Vogeley, K. & Fink, G.R. (2003). Neural correlates of the first-person-perspective. *Trends in Cognitive Sciences, 7,* 38-42.

Vuilleumier, P., & Schwartz, S. (2001). Emotional facial expressions capture attention. *Neurology, 56,* 153-158.

Weierich, M.R, Treat, T.A., & Hollingworth, A. (in press). Theories and measurement of visual attentional processing in anxiety. *Cognition & Emotion*.

Westergaard, G.C., & Hyatt, C.W. (1994). The responses of bonobos (*Pan paniscus*) to their mirror images: Evidence of self-recognition. *Human Evolution, 9,* 273-279.

Wilson, K.D., & Farah, M.J. (2003). When does the visual system use viewpoint-invariant representations during recognition? *Cognitive Brain Research, 16,* 399-415.

Wolford, G., & Morrison, F. (1980). Processing of unattended visual information. *Memory & Cognition*, *8,* 521-527.

Wood, N., & Cowan, N. (1995). The cocktail party phenomenon revisited: How frequent are attention shifts to one’s own name in an irrelevant auditory channel? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 255-260.

Worsley, K.J. (1996). A unified statistical approach for determining significant signals in images of cerebral activation. *Human Brain Mapping, 4,* 58-73.

Xu, Y. (2005). Revisiting the role of the fusiform face area in visual expertise. *Cerebral Cortex, 15,* 1234-1242.

Yarmey, A.D. (1979). Through the looking glass: Sex differences in memory for self-facial poses. *Journal of Research in Personality, 13,* 450-459.

Ying, Z., Jianli, Q., & Jian, Z. (2004). Self-face identification in Chinese students. *Acta Psychologica Sinica, 36,* 442-447.

Young, A.W., Hay, D.C., McWeeny, K.H., Flude, B.M., & Ellis, A.W. (1985). Matching familiar and unfamiliar faces on internal and external features. *Perception, 14,* 737-746.

Young, A.W., Reid, I., Wright, S., & Hellawell, D.J. (1993). Face-processing impairments and the Capgras delusion. *British Journal of Psychiatry, 162,* 695-698.

Yovel, G., & Kanwisher, N. (2004). Face perception: Domain specific, not process specific. *Neuron*, *44,* 889-898.

Zazzo, R. (1993). *Reflets de miroir et autres doubles.* Paris: Presses Universitaires de France.

Zelazo, P.D. (2004). The development of conscious control in childhood. *Trends in Cognitive Sciences, 8,* 12-17.

Zeman, A. (2001). Consciousness. *Brain, 124,* 1263-1289.

Zeman, A. (2005). What in the world is consciousness? *Progress in Brain Research, 150,* 1-10.

Zhu, Y., Qi, J., & Zhang, J. (2004). Self-face identification in Chinese students. *Acta Psychologica Sinica, 36*, 442-447.