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Cognitive Penetration of Early Vision in Face Perception

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Abstract

Cognitive and affective penetration of perception refers to the influence that higher mental states such as beliefs and emotions have on perceptual systems. Psychological and neuroscientific studies appear to show that these states modulate the visual system at the visuomotor, attentional, and late levels of processing. However, empirical evidence showing that similar consequences occur in early stages of visual processing seems to be scarce. In this paper, I argue that psychological evidence does not seem to be either sufficient or necessary to argue in favour of or against the cognitive penetration of perception in either late or early vision. In order to do that we need to have recourse to brain imaging techniques. Thus, I introduce a neuroscientific study and argue that it seems to provide well-grounded evidence for the cognitive penetration of early vision in face perception. I also examine and reject alternative explanations to my conclusion.

Keywords: Visual perception; early vision; late vision; cognitive penetration; affective penetration; early visual processing; top-down modulation; face perception

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1. Introduction

Cognitive and affective penetration of perception refers to the influence that higher mental states have on perceptual systems. This phenomenon is observed when beliefs, expectations, or feelings, moods, among other states, modulate perceptual processing (Churchland, 1979, 1989; Fodor, 1983, 1984, 1988, 2000; Fodor and Pylyshyn, 1981; Raftopoulos, 2001c, a, b, 2009, 2011, 2017). Specifically, this debate concerns the influence of top-down cognitive or affective signals on early stages of visual processing. Cognitive penetration of the early visual system would be observed if persistent illusions,

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such as Müller-Lyer or Ponzo illusions, are the result of neural reorganisation elicited by the constant influence of cognitive states, e.g., our knowledge of perspective and geometry, on early stages of visual processing (Churchland, 1988, p. 174; McCauley and Henrich, 2006). Affective penetration seems to occur when top-down affective states, such as fear or anger, influence early vision so that fearful or threatening objects are perceived more accurately (Gamond et al., 2011; Morel et al., 2009, 2014; Soares and Esteves, 2013; Stolarova et al., 2006; Zhu and Luo, 2012).[1]

Cognitive and affective penetration of perception appears to influence the system's behaviour, its structural organisation, and the processing of the stimuli (content of perception). Penetrating states can modify the system's behaviour by heightening the cortical representation of some stimuli and boosting visual processing (Miskovic and Keil, 2013; Oosterwijk et al., 2016). Emotions like fear seem to modulate the visual processing at very short latencies by sensitising the system to detect potential threat faster (Brendel et al., 2014) and prepare the organism for defensive actions (e.g., flee or fight) (Weymar et al., 2014). Thus, compared to neutral or positive stimuli, fearful stimuli like facial expressions (Marchi and Newen, 2015; Morel et al., 2009; Soares and Esteves, 2013; Wang et al., 2012; Zhang et al., 2017; Zhu and Luo, 2012) or threatening stimuli like angry faces (Zhang et al., 2017) or spiders (Brendel et al., 2014; Domínguez-Borràs et al., 2017) can be detected faster and more accurately. Likewise, attentional mechanisms also seem to be modulated by emotions (Aue and Okon-Singer, 2015; Pourtois et al., 2004; Soares and Esteves, 2013; Zhang et al., 2017), intentions (Land, 2006, 2009; Mole, 2015; Wu, 2013, 2014, 2017), or previous knowledge (Duclos, 2015).

As a consequence of the plastic condition of the brain, higher states appear to cause structural (architectural) changes (Gilbert et al., 2009; Gilbert and Li, 2012; Pourtois et al., 2008). Top-down modulatory states triggered during a perceptual learning task might induce neural reorganisation (Byers and Serences, 2012; Cecchi, 2014; Gatzia and Brogaard, 2017; Hohwy, 2017; Li et al., 2004; Makino and Komiyama, 2015; Zhang et al., 2015). For instance, the beliefs and intentions involved in an intensive training task might be responsible for subsequent long-lasting neural adaptation in the visual cortex (Byers and Serences, 2012; Cecchi, 2014; Rauss et al., 2009, 2011).

Cognitive and affective penetrating states can also affect the processing of the stimuli and modulate the content of perception (Arstila, 2018; Borst and Kosslyn, 2010; Gatzia and Brogaard, 2017; Miskovic and Keil, 2013; Morel et al., 2014; Oosterwijk et al., 2016). Desires (Balcetis and Dunning, 2006, 2007), motivation or optimism (Witt and Proffitt, 2005), and hunger or thirst (Balcetis and Dunning, 2010) can bias the perception of distances and objects' sizes.

The cognitive and affective penetration of perception is of great importance for philosophy, psychology, neuroscience, and other fields like psychiatry, marketing, consumer behaviour, and finance.

From a philosophical perspective, cognitive and affective influences on perception represent an epistemic problem. Perceptual experiences are the foundation of our visual knowledge since it is on the

[1] In this introduction, I have described cognitive and affective penetration of perception with regard to early vision. However, it is worth noticing that the cognitive penetrability debate can also be interpreted with reference to the perceptual experience (Gatzia, 2017; Macpherson, 2012; Siegel, 2012, 2013b; Silins, 2016; Stokes, 2013). In this latter debate, the matter at issue is whether the content of the perceptual experience can be modulated by cognitive or affective mental states, rather than whether the locus of top-down penetrating influences is early vision, late vision, or the perceptual experience itself. In other words, the focus of interest is the phenomenal character of the perceptual experience: what is like to perceive an object (Macpherson, 2011b, p. 129, 2012, pp. 24-28; Siegel, 2012, p. 203; Teufel and Nanay, 2017, p. 18). These two debates — i.e., the penetration of early vision and the penetration of the perceptual experience by higher states — are often considered as independent from and complementary to each other (Fodor, 1983, pp. 73-74; Macpherson, 2012, p. 29; Pylyshyn, 1984, p. 174, 1999, p. 344; Raftopoulos, 2005, pp. 75-76, 2011, p. 8; Siegel, 2013b, p. 699, fn.4; Siegel and Silins, 2015, p. 804, fn. 55; Teufel and Nanay, 2017, p. 18). The focus of this article is the cognitive and affective penetration of the early visual system.

basis of what we see that we are justified in believing one way or another (Engel, 2007; Lyons, 2011; Siegel, 2012, 2013b; Siegel and Silins, 2015). If the perceptual process is corrupted by our cognitive or affective background, we might not see the world as it is but as we want or expect it to be (Fodor, 1983, p. 68; Pylyshyn, 1980). Therefore, we might fail to know the world (Clark, 2016; Lyons, 2011, 2015, 2016; Macpherson, 2012, 2017; Siegel, 2012).

The apparent encapsulation (isolation) of the visual system from cognitive and affective states appears to have behavioural advantages for the speed and the objectivity of perceptual integration (Fodor, 1983, p. 43; Pylyshyn, 1984, p. 155; Raftopoulos, 2001c, p. 188), and the reliability of the visual processing (Fodor, 1983, p. 68). In other words, perceptual modularity seems to make the world safe for knowledge (Lyons, 2011, p. 305). (See also Burnston and Cohen, 2015; Fodor, 1984, 1988, 2000; Pylyshyn, 1980, 1984, 1999, 2003; Raftopoulos, 2001a, 2009, 2017.) However, recent research shows that cognitive and affective influences on perception appear to be the norm of the brain. The subject's cognitive and affective background plays a fundamental role in the way we perceive objects, as it helps to interpret the environment in the most adequate manner (Churchland, 1979, 1989; Clark, 2013, 2014, 2015, 2016; Lyons, 2011; Marchi and Newen, 2015; Machery, 2015; Macpherson, 2012, 2015, 2017; Ogilvie and Carruthers, 2016; Teufel and Nanay, 2017).

A similar ongoing debate is observed in psychology. Theoretical approaches (Balcetis, 2016; Churchland et al., 1994; Collins and Olson, 2014; Hohwy, 2013, 2017; Lupyan, 2012, 2015; Lupyan et al., 2010; Newen and Vetter, 2017; Vetter and Newen, 2014) and empirical evidence seem to show that higher influences on visual processing have consequences for human behaviour. Penetrating higher states might harm social interaction if faces look angrier than they really are (Zhang et al., 2017), discourage actions if distances or heights look bigger than expected (Storbeck and Stefanucci, 2014; Stefanucci and Proffitt, 2009), alter the performance of a task if objects look different (den Daas et al., 2013; Witt and Proffitt, 2005), affect business if beverages taste less palatable than they normally do (Harrar et al., 2011; Piqueras-Fiszman and Spence, 2012; Wanab et al., 2015), and the like. Still, some psychologists argue that there is no conclusive evidence for the cognitive and affective penetration of perception (Firestone and Scholl, 2014, 2015a, b, 2016; Pylyshyn, 1999, 2003).

Finally, the debate extends to the field of neuroscience. A successful interaction with the surrounding world depends on the organism's ability to predict future events and plan behaviour. The brain is continuously storing and updating information about associations between objects, events, and their specific contexts. Rather than passively waiting to be activated by external inputs, the brain takes advantage of stored associations to generate predictions about the world it encounters. Predictions facilitate perception by helping to construct a coherent representation of the incoming inputs based on the stored information (Baars and Gage, 2010; Bar, 2004, 2007, 2009b, a; Bar et al., 2006; Friston, 2005, 2008; Gilbert and Sigman, 2007; Irwin and Thomas, 2008; Kveraga et al., 2007; Panichello et al., 2013; Perlman et al., 2016).

Some predictive processes are achieved by affective and cognitive states that might strengthen visual processing efficiency, enhance synapses, elicit neural reorganisation, and the like (Brendel et al., 2014; Rauss et al., 2011; Weymar et al., 2014). These effects have important theoretical and empirical consequences for brain architecture (e.g., anatomy, plasticity) (Gilbert et al., 2009; Gilbert and Li, 2012; Qin and Yu, 2013), brain functioning (e.g., consciousness, perceptual learning, development) (Bar, 2009b, a; Byers and Serences, 2012; Cheung and Bar, 2014; O´Callaghan et al., 2017; Panichello et al., 2013; Rauss et al., 2011; Rauss and Pourtois, 2013; Trapp and Bar, 2015), and explanatory models (e.g., predictive coding, ERP analysis) (Clark, 2013, 2016; Hohwy, 2013; Rauss et al., 2012; Rauss and Pourtois, 2013; Spratling, 2016). For instance, empirical studies seem to show that higher states modulate early visual areas by influencing visual content and brain architecture

(Brendel et al., 2014; Morel et al., 2009; Pourtois et al., 2013; Rauss et al., 2009, 2012, 2011; Stolarova et al., 2006; Weymar et al., 2014; Zhu and Luo, 2012). Nonetheless, some neuroscientists claim that these results are controversial because they seem to rely on theoretical assumptions regarding how event related potential (ERP) components, such as C1, should be interpreted (Ding et al., 2014; Fu et al., 2010a, b; Fu and Fedota, 2012; Martinez et al., 2001).

The cognitive and affective penetration of early vision has been tackled from different angles in philosophy. Some researchers have focused on understanding the nature of bottom-up and top-down processes in visual perception (Teufel and Nanay, 2017; see Rauss et al., 2011; Gilbert and Sigman, 2007; Gilbert and Li, 2013; for scientific literature). Other philosophers have argued for the necessity of top-down signals to achieve perceptual computation (Marchi and Newen, 2015; Newen and Vetter, 2017; see Bar et al., 2006; Cheung and Bar, 2014; O´Callaghan et al., 2017; Piëch et al., 2013; for non-philosophical sources). Furthermore, theoretical approaches have postulated that top-down effects result from predictive processes in the brain (Clark, 2013; see Fenske et al., 2006; Hohwy, 2013, 2017; Lupyan, 2015; for scientific references). Meanwhile, recent empirical studies seem to provide strong evidence in favour of the cognitive and affective penetration of early vision (Meeren et al., 2008; Stolarova et al., 2006; Zhang et al., 2015; Zhu and Luo, 2012). However, whereas the eager advocates of the impenetrability of perception (e.g., Raftopoulos, 2009, 2017) provide rigorous analyses of empirical evidence against the cognitive or affective penetration of early vision, the same analysis is overlooked in the opposite camp. That is, the upholders of the cognitive and affective penetrability of perception barely scrutinise empirical aspects such as the origin and target of brain signals, their loci, and their time course. The literature on the matter remains thus highly speculative.

This article intends to bridge the above-mentioned gap by providing a detailed analysis of empirical evidence supporting the cognitive penetration of early vision. Firstly, I briefly explain visual processing and what is at issue in the cognitive and affective penetrability debate (section 2). Secondly, I present the problems faced by psychological studies in accounting for the penetration of perception and argue that psychological evidence does not seem to be either sufficient or necessary to support or reject the penetrability of early vision (section 3). In section 4, I scrutinise some empirical findings and claim that they can, at best, show penetration of late vision. Thirdly, I introduce a neuroscientific study and scrutinise its findings with regard to the origin, time course, and impact of cognitive signals in face perceptual areas, as well as their epistemic consequences. I argue then that the study provides well-grounded evidence for the cognitive penetration of early visual face perception (section 5). Later, I refute some alternative explanations to my argument (section 6) and conclude in section 7.

2. Levels of Visual Processing

The visual system is the human interface with the visual world as it represents the objects, events, and properties of our surroundings. Vision or visual perception is the process that begins with the computation of a physical stimulus on the perceptual organ (i.e., the retina) and finishes, e.g., with the generation of a perceptual experience (i.e., the conscious representation a subject has normally while seeing an object).

This process is frequently divided into early and late vision (Cavanagh, 2011; Engel, 1996; Fodor, 1983, 2000; Hayward and Tarr, 2005; Hildreth, 1987; Hildreth and Ullman, 1989; Marr, 1982; Pylyshyn, 1984, 1999, 2003; Raftopoulos, 2001c, a, 2009; Rensink, 2000a, b; Ullman, 1996; Wagemans et al., 2005).[2] Early vision refers to the earliest stage of visual processing. It goes from

[2] These distinctions frequently involve three levels of processing, the first of these levels corresponds to early vision, e.g.,

the treatment of the perceptual stimuli that reach the retina to the computation of basic properties such as colour, shape, orientation, size, and the like (Bear et al., 2016, ch. 10; Marr, 1982, ch. 3; Purves et al., 2004, ch. 11; Stirling, 2000, ch. 7; Tovée, 2008, ch. 4 and 5; Valberg, 2005, ch. 8). This process starts at about 40 ms post-stimulus onset with the activation of the primary visual cortex (the earliest cortical area involved in visual processing). This stage, which lasts for about 60–80 ms, seems to be bottom-up and modular (encapsulated from the subject's intentions, expectations, or emotions) (Engel, 1988, pp. 15-17, 2012, p. 18; Fodor, 1983, pp. 62-86; Pylyshyn, 1999, pp. 334, 361, 2003, pp. 134-136; Raftopoulos, 2001c, a, 2009, 2011, 2017). Thus, the first 100 to 120 milliseconds after stimulus presentation correspond to early vision (Raftopoulos, 2001c, 2009, ch. 2).

Late vision begins at about 100 or 120 ms with the computation of the early visual output and ends, for instance, with the generation of a perceptual experience. In normal subjects the late visual process lasts between 100 and 200 ms; the threshold of consciousness being approximately 200–300 ms post-stimulus onset (Dehaene and Changeux, 2011, pp. 203-207, 215; Lamme, 2003, p. 16, 2004, pp. 869-871; Melloni et al., 2011).

The late visual process is responsible for the recognition and categorisation of objects, so it relies on the observer's cognitive background, memory, and point of view (Clark, 2013, p. 187; Engel, 1996, p. 282; Gilbert and Sigman, 2007, p. 668; Pylyshyn, 1984, pp. 134-135; Raftopoulos, 2001a, p. 427, 2005, pp. 75-76, 2009, pp. 77, 80). The same visual scene will be processed differently if in one case the task concerns objects' size (shape properties) and in another circumstance the distance between objects (spatial relations) (Hildreth and Ullman, 1989, p. 610). In order to deliver a visual experience, the processing depends on the intrinsic interaction between incoming (bottom-up) visual stimuli and cognitive/affective (top-down) states determined by the subject's immediate purposes (Engel, 1988, p. 12; Pylyshyn, 1984, p. 174, 2003, p. 157; Raftopoulos, 2009, p. 77, 2011, p. 8; Rensink, 2000a, p. 28).

There are variegated types of outputs delivered by the visual system. Some of them are unconscious signals that regulate non-visual processes such as biological functions (e.g., circadian rhythms) (Goodale and Milner, 2005, p. 312; Purves et al., 2004, p. 263; Pylyshyn, 1984, p. 172; Tovée, 2008, p. 74; Strettoi and Parisi, 2014) or action (Brogaard, 2011b, 2012b; Buckingham and Goodale, 2010; Goodale and Humphrey, 2005; Milner and Goodale, 2006; Wu, 2011). Others consist in unconscious signals necessary for visual processing (e.g., multisensory and amodal perception) (Brogaard, 2011a; Schirmer and Adolphs, 2017) or behavioural guidance (e.g., subliminal perception) (Gilbert and Sigman, 2007; Gilbert and Li, 2013; Newell and Shanks, 2014). Still, another type of output is the (conscious) perceptual experience (Engel, 2007; Macpherson, 2011a; Siegel, 2013a; Raftopoulos, 2011).

Philosophers (Deroy, 2013; Fodor, 1983, 2000; Raftopoulos, 2001c, a, 2009, 2017) and psychologists (Firestone and Scholl, 2014, 2015a, b, 2016; Pylyshyn, 1984, 1999, 2003) sympathetic with the cognitive impenetrability thesis claim that in spite of the fact that late vision is a stage of processing in which background knowledge and emotions reconcile with perceptual inputs, this is neither necessary nor sufficient to claim that early vision is also top-down modulated (Fodor, 1983, pp. 73-74; Pylyshyn, 1984, p. 174, 1999, p. 344).

While a great deal of evidence supports cognitive/affective penetration of the visuo-motor system (Land, 2006, 2009; McLeod, 1987; Peterson, 1999; Strijkers et al., 2015; Wu, 2013), attentional mechanisms (Cecchi, 2014; Hüttermann and Memmert, 2015; Pourtois et al., 2008; Rauss et al., 2011; Schwartz et al., 2002; Summerfield and Egner, 2009; Wu, 2014, 2017), and late levels of visual

low-level vision in (e.g., Engel, 1996, pp. 225-226; Ullman, 1996; Hildreth and Ullman, 1989).

processing (Balcetis and Dunning, 2010; Levin and Banaji, 2006; Macpherson, 2012; Olkkonen et al., 2008; Payne, 2006; Tallon-Baudry et al., 2011; Zeimbekis, 2015), few studies seem to show conclusive evidence for the penetration of early vision.

3. Psychological Evidence and Cognitive Penetration of Perception

Arguments for or against cognitive/affective penetrability of perception frequently rely on psychological evidence. The subject's behaviour or verbal reports are taken as a confirmation of whether a perceptual system has or has not been penetrated. However, this type of evidence is not sufficient (and not necessary, as I argue later) to account for cognitive or affective penetration of perception.

The first problem regarding psychological studies concerns their inadequacy to exclude any *post-perceptual* effects. Or otherwise, to distinguish cases of penetration of perception from penetration of cognition (Brogaard and Gatzia, 2017; Lyons, 2011). For instance, after being exposed to a series of pictures of female faces, new faces are perceived as more male-looking (Webster et al., 2004). Some researchers might claim that new faces look more manly because of cognitive penetration of perception (e.g., memory modifies what the subject sees). However, this is not the only interpretation.

The above case could be explained by what subjects think to be the case rather than what they see. This is known as the "judgement interpretation" (Deroy, 2013, pp. 97-99; Firestone and Scholl, 2016, pp. 15-17; Lyons, 2011, pp. 304-305; Macpherson, 2012, pp. 39-42; Pylyshyn, 1984, p. 135, 2003, pp. 40-44; Siegel, 2012, p. 206; Stokes, 2013, pp. 656-657, 2013, pp. 655-656; Vetter and Newen, 2014, pp. 65-66; Zeimbekis, 2013). It is observed in studies presenting circumstances in which subjects have to report objects' colours in borderline cases (Brogaard and Gatzia, 2017) or in conditions involving reduced acuity, poor illumination, shapes' complexity (Deroy, 2013, p. 94 and fn. 23), or colour-concept anchoring (Zeimbekis, 2013, p. 168). In the above study, we cannot rule out the possibility that the subjects might have judged the faces as being more male-looking and conclude in favour of cognitive penetration.

Another alternative explanation of the above result is that subjects might have reported what they remember to be the case rather than their current experiences. This is labelled as the "memory interpretation" (Firestone and Scholl, 2016, pp. 15-17; Lyons, 2011, pp. 304-305; Macpherson, 2012, pp. 39-42; Pylyshyn, 2003, pp. 40-44; Siegel, 2012, p. 206; Zeimbekis, 2013; Deroy, 2013, pp. 97-99; Stokes, 2013, pp. 655-656). Reporting a memory is the consequence of studies in which reports are off-line (i.e., the stimulus is reported a long time after it disappeared), or subjects are forced to give an answer even when they did not seem to see the object or saw it partially, and the like. With regard to the above-mentioned study, subjects could have remembered the faces as being more masculine.

These alternative interpretations prevent us from arguing that there is cognitive penetration of perception instead of penetration of cognition. Much of what seems to be cognitive penetration of perception may actually be an entirely post-perceptual phenomenon (Lyons, 2011, p. 304).

The second issue with regard to psychological evidence concerns the *origin* of the penetrating state. They do not show whether the penetrating signal is cognitive, affective, or perceptual. For instance, Wanab et al. (2015) report two cases of penetration of perception: in one of them the colour of beverages (green, yellow, and orange) is influenced by the shape of the glass in which the drink is presented; in the other, the taste of beverages is altered by the colour in which the drinks are presented (see also Harrar et al., 2011; Piqueras-Fiszman and Spence, 2012). These findings demonstrate how contextual factors (shape and colour) change respectively visual (colour) and gustatory (flavour) perception. However, we do not have enough evidence to decide if these effects resulted from intra-modal influences (colour-shape association) in the former case, cross-modal consequences (colour-gustatory association) in the latter case, or from cognitive penetration of perception (memories of shape and colour influence perception). Again, psychological studies are not sufficient to rule out any intra-modal or cross-modal impact in the visual content.

A third problem concerns the *locus* of the cognitive penetration: do higher states affect early or late vision? Subjects' behaviour or conscious reports can show at best that there is cognitive/affective penetration of the experience but cannot tell us the locus of this effect — whether it happens at early or late vision (Fodor, 1983, pp. 73-74; Lyons, 2011, p. 305). Pylyshyn writes: "a psychophysical experiment cannot bypass the cognitive system and directly examine the output of the transducers [early visual systems]" (Pylyshyn, 1984, p. 174; see also 1980, p. 112).

Therefore, behavioural or conscious reports are not sufficient to demonstrate either the origin or the locus of brain signals, so they cannot account for the cognitive/affective penetration of perception. We only have access to the final result of the perceptual process (e.g., perceptual experiences, actions, and the like).

Finally, psychological evidence might not be necessary to account for the cognitive/affective penetration of perception because the effects of the penetration may remain either completely unconscious or inaccessible to the subject. That is, the penetrated content can be computed unconsciously by the motor system to guide action (Brogaard, 2011b, 2012b; Buckingham and Goodale, 2010; Goodale and Humphrey, 2005; Milner and Goodale, 2006; Wu, 2011), by the visual system to regulate behaviour (Brogaard, 2011a, 2012a; Salti et al., 2015), or by cortical areas to improve visual performance (Gilbert et al., 2009; Gilbert and Li, 2013; Gilbert and Sigman, 2007; Chaumon et al., 2008, 2009). In none of these cases would the consequences of the penetrating states be observed at the conscious level (Pylyshyn, 2003, p. 356).

To summarise, psychological studies are not sufficient to decide whether higher states modulate cognition or perception, what their origin is, or whether they affect early or late vision. Moreover, because the effects of the penetrating process may be completely unconscious, psychological evidence might not be necessary either.[3]

To argue for cognitive/affective penetration of early vision, we need some techniques capable of providing evidence on *where*, *how*, and *when* the cognitive/affective signal influences the visual system. Such a methodological approach is provided by brain imaging techniques used in neuroscientific studies.[4] Brain imaging techniques provide both a highly detailed topographic map of brain activation (e.g., fMRI, functional magnetic resonance imaging) and a high time resolution of such activity (e.g., EEG, electroencephalography, and MEG, magnetoencephalography).

For instance, fMRI techniques can supply very detailed neuroanatomical and functional brain activation maps. With regard to the "where" question, they can identify the brain region that triggers the modulatory signal (e.g., the prefrontal cortex) and the area targeted by this influence (e.g., the primary visual cortex). Concerning the "how" question, they can inform us about how the brain is modulated during a perceptual task (e.g., showing improvement in the detection of orientation). EEG and MEG techniques have a high time resolution capable of assessing the origin and destination of electric signals in the order of 2 milliseconds. Time information is fundamental to estimate the "when" question, that is, whether higher signals affect the visual system within the time course of early or late vision.

The virtues of brain imaging techniques are essential to demonstrate cognitive/affective penetration

[3]For other pitfalls regarding cognitive/affective penetrability of perception see Firestone and Scholl (2014, 2015a, b, 2016); Lyons (2001); Macpherson (2012); Stokes (2013).

[4]Notice that my argument radically contrasts with Stokes's (2013) who claims that "empirical evidence for (or against) cognitive penetration is best drawn from considerations and studies at the behavioural or psychological, rather than neurological, level" (Stokes, 2013, p. 654).

of perception. Nonetheless, it is important to notice that neuroscientific studies alone do not seem yet to provide evidence for the penetration of visual perception:

> It is not the visual complexity of the class to which the cell responds, nor whether the cell is modulated in a top-down manner that is at issue, but whether or not the cell responds to how a visual pattern is *interpreted*, where the latter depends on what the organism knows or expects. If [early] vision were cognitively penetrable one might expect there to be cells that respond to certain interpretation-specific perceptions. In that case whether or not the cell responds to a certain visual pattern would appear to be governed by the cognitive system in a way that reflects how the pattern is conceptualised or understood. (Pylyshyn 1999, p. 347, 2003, pp. 69-70, see also 1984, p. 172)

In fact, while neuroscientific studies provide very rich evidence of brain activation during perceptual tasks (i.e., the where, how, and when questions), psychological evidence provides the basis to interpret brain activation in the light of the subject's behaviour (i.e., the why question).[5] Psychology helps us to determine *why* higher signals should be considered as cognitive or affective penetration of perception rather than as residual, non-task related, or any other type of influence.

To sum up, the combination of psychological and neuroscientific studies is a requirement to account for any form of cognitive or affective penetration of visual perception. The latter provide evidence of the underlying physiological processes upholding mental states (origin and target of the signals) necessary to account for different forms of penetration (i.e., cross-modal, motor, cognitive, or affective) and their loci (i.e., early or late vision). The former accounts for the conscious life and behaviour of the subject necessary to interpret these physiological data.

4. Cognitive Penetration of Late Vision

To show cognitive or affective penetration of late vision, empirical studies need to demonstrate, in addition to behavioural consequences, that top-down higher signals affect the visual system within the time window between 100 to 300 ms post-stimulus onset.

Balcetis and Dunning (2006) show that rewards and penalisations modulate perceptual content. Subjects were rewarded if they identified a figure as a letter or penalised when they identified the same figure as a number. Some of these studies seem to show cognitive penetration of late vision (Balcetis and Dunning, 2006, pp. 617-618). In a series of studies on knowledge influences on colour perception, Witzel et al. state that their "findings provide further evidence that object recognition and colour appearance interact in *high-level* vision" (2011, p. 44, my italics). Likewise, Hansen et al. (2006, p. 1368) and Olkkonen et al. (2008, p. 12) claim that their "results show a high-level cognitive effect on low-level perceptual mechanisms". Despite the fact that the authors took advantage of Bayesian modelling which seems to indicate cognitive penetration of late vision (Gatzia, 2017, pp. 16-17; Hansen et al., 2006, p. 1368), the lack of information about the time course of visual processing in the above-mentioned studies might still cast some doubt on this conclusion.

In a series of studies led by Payne (2001, 2005), people's expectations seem to affect visual perception. When participants expected to see a gun in a picture, they reported this object rather than the hair dryer or the pair of pliers they were presented with. However, the authors claim that these studies might show an effect on judgements rather than on perceptual outputs (Payne et al., 2005, p. 47). They explain that when the subjects did not see the object or only saw part of it, they guessed

[5] Notice that with a detailed and reliable neural map of functional and brain activation it would be possible to determine cognitive/affective penetration of perception without turning to psychological studies. However, this claim might be too strong and I intend to avoid this controversy here.

or judged what the object was. On the contrary, when they saw the whole object participants did not misidentify it. (See Siegel, 2013b, p. 699, for this explanation based on an unpublished study of Payne.) The lack of control on brain activity prevents the authors from concluding that there was any form of cognitive penetration of perception. Despite this conclusion, in a replication of these studies using ERP, Payne (2006) revealed that the time course of top-down influences was located within the time window between 200 and 300 ms (Payne, 2006, p. 287); that is the end of the late visual processing. These results thus provide evidence to account for the cognitive penetration of late vision or the perceptual experience.

Other empirical studies have suggested that the value of a currency associated to the subject's social circumstances can alter the perceived size of coins (Blum, 1957; Bruner and Goodman, 1947; Bruner and Rodrigues, 1953; Dukes and Bevan, 1952). However, the findings could also reflect the subjects' judgement that the coins were bigger. Differently, in an experiment measuring the psychological effects of monetary value using brain imaging techniques, Tallon-Baudry et al. (2011) clearly show that higher states related to monetary value do penetrate the late visual system and modulate visual perception.

Recent experiments using EEG and MEG recordings appear to provide good evidence for the cognitive and affective modulation of late vision. These paradigmatic cases occur in face perception which necessitates the interaction of memory with physical attributes (Calvo et al., 2012; Frühholz et al., 2011; Luo et al., 2010, 2016; Marchi and Newen, 2015; Mattavelli et al., 2013; Vuilleumier and Pourtois, 2007).

To bypass the problems raised by psychological studies we need to have recourse to brain imaging techniques. In the next section, I examine an empirical study from neuroscience which provides compelling evidence for the cognitive penetration of early vision in face perception.[6]

5. Cognitive Penetration of Early Vision in Face Perception

On a first encounter with a person we have never met before, the brain tends to spontaneously infer personality traits and social categories (Bar et al., 2006; Gamond et al., 2011; Kveraga et al., 2007; Willis and Todorov, 2006). Inferring someone's personality from her face or her photograph is a pervasive and automatic brain behaviour that occurs even when no information about the subject's character is available. In less than 40 ms of exposure the brain can gather the first impressions about personality traits (Bar et al., 2006).

Facial expressions provide essential information for human interaction. They are crucial features

[6] Marchi and Newen (2015) have recently argued in favour of the affective penetrability of face perception. However, it is worth noticing that their argument is substantially different from the one considered in this paper. Firstly, and this is a minor consideration, their argument concerns affective penetrability of the face perceptual system, a common influence in face perception (Calvo and Beltrán, 2013; Frühholz et al., 2011; Miskovic and Keil, 2013; Pourtois et al., 2004, 2013; Wang et al., 2012), while mine involves cognitive penetration. Secondly, Marchi and Newen (2015) claim that facial expressions are processed as "wholes", what means that the affective evaluation of a face occurs at some level within the computation of physical features, rather than at post-perceptual stages (e.g., judgement). Yet, this interpretation is not different from the current and mainstream understanding of face perceptual processing in which higher states are integrated into physical features (Calvo and Beltrán, 2013; Gauthier, 2010; Rolls, 2007; Vuilleumier, 2007; see also section 5). Thirdly, within conventional models of face visual processing, the combination of physical and emotional attributes takes place before the threshold of consciousness (Dehaene and Changeux, 2011; Lamme, 2003, 2004; see also section 2) but still at late stages in the perceptual analysis (Hadjikhani et al., 2009; Luo et al., 2016; Mattavelli et al., 2013; see also section 5), so that this integration will not count as a case of penetration of early vision. Finally, while Marchi and Newen make a valuable contribution to the penetrability debate, by claiming that their argument "admits some degrees of CP [cognitive penetration]" (2015, p. 4), their explanation remains speculative regarding the locus of top-down influences in face perception (see section 3) and casts doubt on whether higher states can modulate early vision.

from which we infer the subject's state of mind, feelings, and intentions (Morel et al., 2009). Due to the importance that the recognition of people's identity and intentions has in our lives, the face-perceptual system appears to have a privileged access to cognitive and affective information (Calbi et al., 2017; Calvo and Nummenmaa, 2011; Frühholz et al., 2011; Marchi and Newen, 2015; Schirmer and Adolphs, 2017). The association of physical features to memories of personality traits collected in previous encounters shapes the neural response to newly encountered faces (Gamond et al., 2011, p. 1416).

Cognitive or affective modulations on face perception can be translated into behavioural advantages. Higher states can facilitate and speed up stimulus processing, enhance attentional gating, cause plasticity-related changes, and the like (Pourtois et al., 2013; Rauss et al., 2011). Likewise, such top-down effects suppose major advantages for motor responses. The information on a nearby potential threat conveyed by an angry or a fearful face is prioritised and rapidly transmitted through the dorsal stream to produce an immediate motor reaction (e.g., to flee) (Lambert and Wootton, 2017; Marrett et al., 2011; Milner and Goodale, 2006).

Because the perception of faces results from the active combination of facial features and previous memories of personality traits, it is a highly flexible behaviour that can be manipulated experimentally (Gamond et al., 2011, p. 1415). For example, the perceptual context highly influences the emotion category of a facial expression (Calbi et al., 2017; Marchi and Newen, 2015) and faces presented along with a positive description of emotions are perceived as more positive in following encounters (Todorov et al., 2007).

The last decade has been very prolific in empirical studies on face perception supporting cognitive and affective penetration of early vision. Pictures with affective meaning such as averse or fearful faces elicit greater modulations in the visual cortex compared to neutral or happy faces (Calvo and Beltrán, 2013; Morel et al., 2009; Zhu and Luo, 2012). The emotional response elicited in the detection of fearful faces evokes a larger activity in the primary visual cortex as the result of top-down influences observed in the time window from 60 to 90 ms (Gamond et al., 2011; Morel et al., 2009, 2014; Pourtois et al., 2004; Stolarova et al., 2006; Zhu and Luo, 2012). Meeren et al. (2008) have demonstrated that face inversion perceptual categorisation is modulated by top-down cognitive effects between 70 to 100 ms. (See Rauss et al., 2011, pp. 1245-1247, for a review.)

Gamond et al. (2011) have conducted a particularly compelling experiment which shows that the discrimination of facial expressions depends on cognitive penetration of early vision. Using MEG recordings, Gamond et al. tested a face categorisation task where subjects had to judge whether a face was either flexible or determined. The authors show that learned arbitrary associations between a facial trait and a personality feature affect the subject's visual content of new faces.

The experiment was run in three subsequent sessions (pre-feedback, feedback, and post-feedback) and recruited two groups of participants. In the pre-feedback phase, while looking at a screen, subjects were presented with different faces (they varied in inter-eye distance: small or large) and asked to report whether the faces were flexible or determined. Their answer showed that determined and flexible faces were indistinctly associated to small or large eye separation. During the second session (the feedback), subjects repeated the same task but after each response (flexible or determined) they were given feedback about the accuracy of their answer. Unknown to the participants, the feedback represented a form of training: it consisted in an arbitrary association of small or large inter-eye distance with the flexible or determined personality trait. One group of participants was given positive feedback if they judged a face with small eye separation as flexible and a face with large inter-eye distance as determined. And a negative feedback if they judged the faces differently. The association was reversed for the other group, which was given positive feedback when they judged faces with small inter-eye distance as determined and faces with large eye separation as flexible. (Gamond et al., 2011, pp. 1416-1418) After the feedback session of about 15 minutes, subjects undertook the third phase in which they repeated the same task as in the initial phase (without feedback).[7]

The study shows that after the feedback phase the association between the physical feature (small or large inter-eye distance) and the personality trait (determined or flexible) was manipulated. During the initial phase subjects indistinctly associated determined and flexible traits to small and large inter-eye distance. Differently, during the post-training session, subjects identified the faces as determined or flexible according to the feedback given to each group. The results seem to show that during the pre-feedback session subjects *judged* the faces to be flexible or determined, but during the post-feedback phase their responses were based on *perceptual* changes.

In order to support these findings, it is paramount to understand visual processing of the face. Human face perception relies on a specialised subsystem localised in visual areas and elsewhere in the brain (Gauthier, 2010; Mattavelli et al., 2013; Sinha et al., 2010; Vuilleumier, 2007). The primary areas for human face perception are the fusiform face area (FFA) (Kanwisher, 2001; Kanwisher et al., 1997; Liu et al., 2010), the lateral occipital face area (OFA), and the superior temporal sulcus (STS). Other areas intimately involved in face perception are the amygdala, some regions of the temporal pole (TP), and the ventromedial prefrontal cortex (vmPFC) (Harmer et al., 2001; Liu et al., 2010; Vuilleumier, 2007).

Conventional models of face perceptual processing assume that the perceptual analysis of faces and the processing of facial emotions occurred separately. At a first and early stage, the visual system processes physical features in a bottom-up manner. Later, top-down signals resolve the processing of emotional expression of the face. According to this model the analysis of emotional expressions occurs about 170 ms after stimulus onset (Morel et al., 2009, p. 85). Face perceptual areas (FFA, OFA, and STS) are directly implicated in the first stage of face perception, while higher cognitive and affective structures (vmPFC, TP, and the amygdala) are recruited later in the process.

Gamond et al.'s (2011) empirical study challenges the traditional interpretation (i.e., physical face properties are processed first and emotional features later). During the post-feedback, memories of prior experiences (unconscious associations learned during the feedback session) modulated neurons in face-responsive regions sensitive to inter-eye distance (Gamond et al., 2011, p. 1424). Face perceptual areas were modulated by higher re-entrant signals as early as 60-70 ms after stimulus onset (Gamond et al., 2011, pp. 1419, 1422). Given that these top-down influences were not present in the pre-feedback phase, we can assume that the top-down neural activity in the post-feedback session was produced by the learning process (Gamond et al., 2011, p. 1419).

From a neuroanatomical viewpoint, top-down effects observed in the FFA and OFA at about 60-70 ms stem from two independent groups of higher regions. The first group, which includes lateral temporal (LT) regions and the inferotemporal (IT) lobe, is intrinsically related to memory and concepts (Rolls, 2007). This activity could have a role in deciding whether someone is flexible or determined. The second assembly, which involves the orbito-temporopolar complex composed of the orbitofrontal cortex (OFC) and temporopolar (TP) regions (Gamond et al., 2011, pp. 1422-1424), appears to be responsible for social and emotional behaviour. The OFC plays a key role in social and emotional

[7] During the pre-feedback and post-feedback phases, each trial started with a central fixation point (700 ms to 1 s), followed by a face presented for 400 ms replaced afterwards by the fixation point for 2.5 s. Subjects were asked to report whether the faces (with small or large inter-eye distance) were flexible or determined by pressing a button after the presentation (within the time window of 2.5 seconds). A blank screen shown between 2 to 3 seconds separated the trials. In the feedback phase, participants received a 2-second feedback immediately after their responses which indicated whether their response was correct or incorrect.

interaction (Rolls, 2007) while the TP appears to link specific memories of a person with perceptual representation of faces. The orbito-temporopolar complex seems to help the perceptual process to establish association rules to determine when someone is flexible or determined (two social concepts) (Gamond et al., 2011, p. 1424). Notice that because these two groups have cognitive functions, we can then argue that cognitive signals have influenced the face perceptual system and cause cognitive penetration of perception.

Furthermore, the top-down signals modulated the activity of neurons sensitive to inter-eye distance as early as 60-70 ms (Gamond et al., 2011, pp. 1422-1424). Therefore, due to the fact that this higher modulation was measured within the time window of early vision, we can argue that there is cognitive penetration of the early face perceptual system.[8]

Despite this conclusion, there could be alternative explanations for the study results. First, the changes in stimulus detection observed after the training could have been produced by the adaptation of the visual system to the task. Second, the subjects' responses might reflect their judgement rather than a genuine perceptual phenomenon. Let's examine the results in the light of these alternative explanations to rule out these objections.

6. Alternative Explanations to Cognitive Penetration of Early Vision

From the mainstream viewpoint, all the physical features of a face are first processed bottom-up and in parallel (at the same time and without preferences for each other). Later, top-down influences achieve the emotional analysis and the face would be perceived as flexible or determined. However, Gamond et al.'s study shows that a short training associating personality traits to facial features can modulate earlier stages of this process.

Brain imagining techniques show, on the one hand, that during the post-feedback session, cognitive top-down effects modified early face visual processing: i.e., the visual system represented the face as flexible or determined. "[T]he manipulated variable clearly affected early neural responses, showing that the brain evaluates the relevant feature at early processing stages" (Gamond et al., 2011, p. 1423). On the other hand, the study reveals that subjects did not judge whether faces were flexible or determined; they actually saw the faces as having personality traits (Gamond et al., 2011, pp. 1419-1423).

In spite of this conclusion the authors argue that there could be alternative explanations for their findings. Firstly, changes in visual content may not be truly produced by reentrant cognitive states resulting from the training but instead by the habituation of brain networks or increases of attention. Secondly, even if there were cognitive influences, they could have no impact on perceptual content. During the post-feedback, the responses might reflect judgements rather than genuine changes in perceptual content.

With regard to the first alternative, changes in perceptual content might have resulted from the habituation of visual networks to the salience of inter-eye distance repeated across stimuli. This can

[8] It is worthwhile to remark that the face perceptual system is different from the visuo-motor system. First, early face perceptual areas such as OFA and STS are outside the visual system (defined in terms of the dorsal and ventral streams). However, the early face perceptual system shares similar properties with early vision: it is considered as a modular visual system (Fodor, 1983, p. 47; Pylyshyn, 1999, p. 413; Pylyshyn, 2003, p. 147). Pylyshyn argues that "[t]he impenetrability of the early vision system is obviously compatible with there being other impenetrable systems. Among those that have frequently been proposed are the language system and the *face recognition system*" (Pylyshyn, 1999, p. 413, my italics). Although the face perceptual system and the visual system are independent from each other, they intimately interact and share similar characteristics (Fodor, 1983, p. 47; Pylyshyn, 1999, pp. 401, 413).

occur because subjects were exposed to faces which shared the same physical feature. Thus, cognitive influences might play no role in the identification of the personality trait (flexible or determined).

To rule out this hypothesis, MEG results gathered at the beginning of both the pre-feedback and post-feedback phases were compared to the data obtained at the end of the same sessions. No significant habituation was detected within the phases: the sensitisation to small and large inter-eye distance was not significant between the beginning and the end of the same session (Gamond et al., 2011, pp. 1419-1421). Moreover, other face properties which varied across pictures were salient all along the study, namely eye brightness and face aspect ratio.[9] If the improvement in inter-eye distance detection was produced by habituation, eye brightness and face aspect ratio should have produced habituation during the feedback as well. However, neurons sensitive to these facial features did not increase their activity after the learning session. Only neural activity concerning inter-eye distance was affected by the training (Gamond et al., 2011, p. 1421). In addition, the repetition effects due to familiarity (Bar et al., 2006; Chaumon et al., 2008; Dambacher et al., 2009; Summerfield et al., 2008), another element suspected of being at the origin of early brain activity, was also ruled out. Each image was seen only once during the experiment to avoid the impact of visual memory in perceptual processing (Gamond et al., 2011, pp. 1416-1418).

Another criticism indicates that neural activation after the learning could have been produced by an increase in attention to the picture's eye region rather than by cognitive states (Gamond et al., 2011, pp. 1419-1421). However, despite the fact that other physical features were also salient, attentional influences directed to the eye's region only increased neural activity sensitive to inter-eye distance (Gamond et al., 2011, p. 1421). In other words, task-irrelevant salient features (i.e., eye brightness or face aspect ratio) for which participants were not trained did not elicit post-training early modulations.

To sum up, re-entrant cognitive signals affecting early visual processing at the post-feedback phase seem to be specifically produced by the training. Alternative explanations such as sensitisation to face configuration, repetition effects due to familiarity, and increase of attention due to the salience of face features can be rejected. The authors write:

> In sum, the difference of magnetic responses to large and small inter-eye distance faces found in the post-feedback phase did not seem attributable either to a mere sensitisation to the intrinsic structure of the stimulus set or to a non-specific increase of attention toward the eye region. Rather it seemed that the regular association between inter-eye distance and the subject's response introduced during the feedback phase resulted in sensitised brain responses to inter-eye distance, with differentiated responses to large and small inter-eye distance faces as early as between 60 and 85 ms. (Gamond et al., 2011, p. 1421)

The second alternative explanation states that the subject's report could reflect the participant's judgement rather than a perceptual phenomenon. However, several factors disprove this claim. First of all, reaction times in the post-feedback did not change with regard to the initial session: they were similar in both phases (Gamond et al., 2011, p. 1419). Second, the number of responses corresponding to the reinforced association did not increase in the post-feedback session. In the pre-feedback phase, determined and flexible faces were indistinctly related to small or large inter-eye distance. Subjects attributed the same personality trait (e.g., flexible) to both small and large inter-eye distance. During the post-feedback session the association strictly depended on the learned link between inter-eye distance and personality trait. Subjects in the same group did not identify the same inter-eye distance with two personality traits. Had the learning affected the subjects' judgement, there would have been cases in

[9] Face aspect ratio is the proportional relationship between the face's width and height, a relation to which face recognition neurons are highly sensitive.

which the same inter-eye distance would have been attributed to both personality traits, but this did not happen. Instead, the connection between the personality trait and the physical feature occurred at an early level of the visual processing so subjects made no mistake in the identification. (Gamond et al., 2011, p. 1419) Third, neural activation was different across the sessions. MEG results obtained before and after the feedback show different activation patterns between pre- and post-feedback phases. During the initial phase brain activation did not reflect any link between memory and physical attribute. Nevertheless, after the training, the subjects' reports were intimately related to the neural associative pattern linking personality traits to inter-eye distance. (Gamond et al., 2011, pp. 1419-1421) Fourth, post-study questionnaires confirmed that the participants did not report the personality trait consciously using the inter-eye distance for their judgements. They were not aware of the association between inter-eye distance and personality features so did not have explicit knowledge of their link. (Gamond et al., 2011, pp. 1419, 1423)

To summarise, after the feedback session cognitive states affected the face perceptual system at early stages of visual processing. Subjects did not judge that the faces were flexible or determined. Instead, cognitive states modulated early visual content so that their perceptual experiences did represent the faces as flexible or determined.

7. Conclusion

The case study analysed in this paper shows that the perceptual content of physical properties (inter-eye distance) was influenced by the conceptual content of personality traits (flexible or determined). Top-down signals neither increased sensitisation to visual features nor modulated attentional mechanisms. In addition, subjects' responses in the final session did not reflect their judgement but a real perceptual phenomenon resulting from the association between mnemonic (personality traits) and perceptual (physical attributes) contents. (Gamond et al., 2011; Bar, 2009b; Bechara et al., 2000).

Furthermore, cognitive states modulated perceptual content within the time window of early vision. The higher signals (unconscious memories gathered during the feedback phase) influenced neurons sensitive to inter-eye distance as early as 60-70 ms post-stimulus onset.

Notice, furthermore, that cognitive penetration occurred synchronically. The study shows that during the post-training phase cognitive states related to face recognition and categorisation were simultaneous with the processing of physical facial features (Gamond et al., 2011, p. 1423).

The case study provides then compelling evidence for the cognitive penetration of early vision. The categorisation of faces does happen at early visual stages of processing. These empirical findings show that neuronal activation "depends on what the organism knows or expects"; neurons "appear to be governed by the cognitive system in a way that reflects how the pattern is conceptualised or understood" as Pylyshyn (1999, p. 347) demands. Therefore, early vision is cognitively penetrable.

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