In press: Consciousness & Cognition

Varieties of cognitive penetration in visual perception

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Abstract

Is our perceptual experience a veridical representation of the world or is it a product of our beliefs and past experiences? Cognitive penetration describes the influence of higher level cognitive factors on perceptual experience and has been a debated topic in philosophy of mind and cognitive science. Here, we focus on visual perception, particularly early vision, and how it is affected by contextual expectations and memorized cognitive contents. We argue for cognitive penetration based on recent empirical evidence demonstrating contextual and top-down influences on early visual processes. On the basis of a perceptual model, we propose different types of cognitive penetration depending on the processing level on which the penetration happens and depending on where the penetrating influence comes from. Our proposal has two consequences: 1. the traditional controversy on whether cognitive penetration occurs or not is ill posed, and 2. a clear-cut perception –cognition boundary cannot be maintained.

Keywords: cognitive penetration, visual perception, early visual processes, V1, top-down modulation, contextual influences, predictive coding, perception-cognition boundary, philosophy of mind

1. Introduction

When we visually perceive the world, to what extent is our visual perception influenced by our beliefs, desires or cognitive mental states? Can we draw a line between perceptual processes that are never influenced by cognitive inputs and those processes that are always influenced by cognitive factors? In other words, are there cognitively impenetrable perceptual processes?

Cognitive penetration taps into questions that lie at the heart of understanding how perception works. This includes at least two important questions, namely, how a perceptual experience arises and whether it can play the foundational role to be a truth-preserving source of knowledge of the world. Proponents of cognitive impenetrability claim that the cognitive architecture of perception includes some modules (in the strict sense) with functionally encapsulated perceptual processes, and that these processes are the foundation of our knowledge. In contrast, proponents of cognitive penetrability deny the existence of any perceptual module in a strict sense. By accepting that a cognitive content from our memory system may influence our perceptual experience in some situations, they claim that there is no strict borderline between even early visual processes and our background knowledge and higher cognitive states. Thus, human knowledge is not grounded on some absolute truth-preserving perception mechanism but human knowledge (for individuals and for scientific communities) is nevertheless grounded on perception. This paper focusses on the debate about the cognitive architecture underlying cognitive penetration. After developing our multiple-level account of cognitive penetration we will outline that this enables us to avoid skepticism about grounding knowledge on perception.

We will first briefly address how we think perception is related to cognition and define what we mean by cognitive penetration. Then we will summarize the debate on cognitive penetration in the philosophy of mind literature and review some of the recent evidence from the neuroscience and psychology literature. We will focus on visual perception and particularly on the influence of early visual processes by contextual information and cognitive factors. On the basis of this empirical evidence we will argue that cognitive penetration takes places, even when it is understood in a narrow sense (as defined by Pylyshyn, 1999). We argue that we have to account for a plurality of associative processes in the mind anyway and thus should change perspective: Cognitive penetration is best understood in a broad sense as top-down influences on perception by cognitive contents. When analyzing cognitive penetration in this broad sense, different types of cognitive penetration should be distinguished. We suggest how these different types may be implemented within the perceptual processes of the brain with the aid of a four-stage model of perception and which consequences this position has for classical accounts of cognitive penetration and the cognition-perception boundary. Our alternative account allows systematizing top-down influences in the emergence of perceptual experience.

1.1. Situating the debate on cognitive penetration: the question of a perception-cognition boundary

An important open question is how visual perception is related to cognition. To outline the debate, we need at least intuitive concepts of visual perception and cognition. Visual perception is the organization of visual inputs typically coming from the environment resulting in a conscious visual percept. Cognition is usually understood as a process of transforming an informational input which has already some level of unification (in the case of visual input, e.g. a percept) by psychological processes like learning, memorizing, imagining, attending, considering, decision making, linguistic expression etc. The standard model characterizing the relation between perception and cognition is the so-called sandwich model (Hurley, 1998) according to which cognition is a process presupposing the perception of the environment and then triggering an action. Perception is an independent process and a presupposition for cognition and cognition is an independent process which is presupposed to initiate a "reasonable" action. Perception, cognition and action are independent processes while cognition is pressed as the cheese between perception and action as the sandwich halves. This classical view of perception has been radically questioned by O'Reagan and Noë (2001) who argue that several phenomena like inattentional blindness and change blindness can best be explained by characterizing perception as a way of acting: "What we perceive is determined by what we do (or what we know how to do); it is determined by what we are ready to do. In ways I try to make precise, we enact our perceptual experience; we act it out." (Noë, 2004). Since action is seen as interconnected with cognition, it is a consequence of this view that perception is no longer separable either from action or from cognition. Along the same line, we can observe the development of dynamic systems theory which argues that we have to account for online coupling of action and perception (van Gelder, 1995) with the same consequence that perception and cognition are inseparably interconnected. Which is the correct view? Can we separate perception and cognition as suggested by the classical sandwich model which was the only background model of cognitive science until the early 1990s? Or is perception so interconnected with cognition that it cannot even be analyzed as a partially independent process? To come to an adequate account of the role of perception in relation to cognition, we have to specify central processes involved in cognition according to a starting intuition: we suggest that at least activating memorized mental images, on the one hand, or activating semantic background knowledge of objects, situations, persons etc., on the other, are typical cognitive processes. If we agree on this – for the sake of argument – then to clarify the relation of perception and cognition is directly connected with the question of cognitive penetration: do activations of mental images and background knowledge modify our visual experience in a situation? If perception is cognitively impenetrable, the answer is no. We will argue that the thesis of cognitive impenetrability is implausible, but that the most fruitful way to account for the most important data on cognitive penetration is not to give up any separation of perception and cognition but to develop a model of a cascade of processing levels which are partially independent but at the same time account for instances of cognitive penetration.

1.2. Cognitive Penetration of perceptual experience – definition of terms

In this paper, we will focus on the penetration of perceptual experience by cognitive factors. In terms of perception, we will consider the veridical perception of objects and scenes (leaving hallucinations aside). We define perceptual content within a subject-object relationship in which an object within a situation causes a perceptual experience in a subject, i.e. causes a percept. Furthermore, at the level of the percept, two aspects could be distinguished – the content of the percept and whether it is consciously or unconsciously perceived. Both aspects are orthogonally divided (Vosgerau, Schlicht & Newen, 2008). In this paper, we will focus on the content of perceptual experience and leave the aspect of consciousness aside. For simplicity, we will focus on visual perception as the visual system is best researched, but our position may be equally valid for perception in other sensory modalities.

From a philosophical perspective, we have to specify what we mean when we speak of cognitive penetration: cognitive penetration describes an influence of higher cognitive states (including a cognitive content) on a perceptual experience caused by a given sensory input (and not the judgment of this experience) while the state of the sensory organs (in terms of spatial attention and sensory input) is held constant. What is held constant is: 1. the object or scenario causing the visual input, 2. the perceptual conditions, 3. normally functioning sensory organs and 4. the absence of spatial attentional shifts [1](see MacPherson, 2012). If an influence of a cognitive content can nevertheless change the perceptual experience, this is a case of cognitive penetration in a narrow sense. Which entities may cause the penetration? These are higher cognitive states including contextual expectations or contents stored in memory (i.e. beliefs, desires, expectations, knowledge, past experiences, mental images). What gets penetrated? This is the percept, i.e. the features of our experience. What is the nature of that relation? Regarding the question on whether cognitive penetration is a causal (Siegel, 2005) or a rational (Pylyshyn, 1999) relation, we take the side of Siegel and argue that it is sufficient if there is a causal relation between a higher cognitive state and the percept that is influenced by it. Cognitive penetration need not involve a relation such that the contents of both states are in addition logically related: It is not plausible to claim that the content of a higher cognitive state rationally implies the content of the percept: If a cultural background influences the perception of a picture (e.g. Masuda & Nisbett, 2001; Ishii et al., 2014) then this is a paradigmatic case of cognitive penetration even if the content of the cultural specificities is not logically related to the characteristics of the perception. A working definition of cognitive penetrability is the following:

„If visual experience is cognitively penetrable, then it is nomologically possible for two subjects (or for one subject in different counterfactual circumstances, or at different times) to have visual experiences with different contents while seeing and attending to the same distal stimuli under the same external conditions, as a result of differences in other cognitive (including affective) states."(Siegel, 2012)

We would like to specify even more precisely the relevant *narrow sense* of cognitive penetrability, offered by Siegel's definition(covering the same features as MacPherson, 2012): this can be done by describing which type of alternative analysis of an unexpected phenomenon like the influence of a cultural content on our visual experience would *not* count as cognitive penetration in the narrow sense: If the influence is an influence (a) only on our *judgment* or (b) only on our memory system, i.e. by activating a new memory content only modulating the judgment but not the visual experience. Sometimes defenders of cognitive impenetrability characterize a further kind of acceptable influence which they call (c) intraperceptual modulation. The key idea is that alleged cases of cognitive penetration can be explained by the interaction of two visual inputs processed in the same perceptual module at the same time (Pylyshyn, 1999, p. 343). However, this strategy of explanation is only available if the idea of perceptual modules can be established which we deny. Cognitive penetration in a narrow sense can thus be described in more detail by an influence of a (non-perceptual) cognitive content on perceptual experience despite the fact that our perceptual

[1] We focus here on the absence of shifts in spatial attention. However, some cognitive contents penetrating perception might be inherently more attention grabbing than others (in terms of object-based or content-based attention) and thus some forms of cognitive penetration may be caused by top-down attention. Given that the inherent attentional valence of cognitive contents is a property of this content, we do not wish to exclude this possibility and instead regard object- or content-based top-down attention as one form of cognitive penetration.

conditions are stable, on the one hand, and that the three alternative explanation strategies cannot be applied.
In the first step, we aim to show that cognitive penetration in a narrow sense exists. In a second step we argue for a change of perspective: if cognitive penetration in the narrow sense exists, then there are no perceptual modules in a strict sense and we should distinguish different types of top-down influences. We argue that there are several types of cognitive penetration (despite the fact that some philosophers do not classify cognitive penetration in the broad sense as a clear case of penetration at all). This terminological decision has the advantage of highlighting common features of these top-down influences. Furthermore, it provides support for a new perspective on perception: our visual experience is not the product of a bottom-up encapsulated modular process but the product of an embodied perception-expectation-action loop which is implemented for a cognitive system by a highly flexible multiple integration of bottom-up and top-down processes. Thus, the visual percept is the product of provisional and probabilistic feature integration and re-weighting processes that may lead to conscious visual experience as a stable intermediate product in the permanently ongoing process of predictive coding. To make a change of perspective plausible, we aim to argue in detail for cognitive penetrability and to show in detail how multiple top-down influences can be analyzed.

2. Arguments from philosophy and neuroscience: is perception encapsulated and cognitively penetrable?

Whether our perceptual experience is cognitively penetrable by beliefs, prior knowledge, expectations and past experiences is still a debated topic in philosophy of mind and cognitive science. Fodor (1983) and Pylyshyn (1999) started the debate by presupposing the idea that early visual processes are organized as a module in Fodor's sense, i.e. they are inborn, domain specific and informationally encapsulated. In his seminal paper on the topic, Pylyshyn (1999) argued that early visual processes are functionally encapsulated and as such cognitively impenetrable. He conceptualizes early visual cortex as an encapsulated module which receives possibly attentionally modulated responses from the eye as input and outputs shapes, size, colors and other typically "early" visual features. He holds the position that the content of this module's output is impenetrable by cognition. It is important to notice that Pylyshyn does not argue against all kinds of top-down influences but he thinks that there are only two types of top-down influences from cognitive contents, i.e. modification of attention before early visual processes start to work and recognition of memorized patterns after early visual processes have done their job:

„Our hypothesis is that cognition intervenes in determining the nature of perception at only two loci. In other words, the influence of cognition upon vision is constrained in how and where it can operate. These two loci are: (a) in the allocation of attention to certain locations or certain properties prior to the operation of early vision(…) (b) in the decisions involved in recognizing and identifying patterns after the operation of early vision. Such a stage may (or in some cases must) access background knowledge as it pertains to the interpretation of a particular stimulus." (Pylyshyn, 1999)

Also Raftopulos (2001) argues for cognitive penetrability of perception, providing a refined version of Pylyshyn. He argues that we have to distinguish non-cognitive perception and cognitive observation: we can grant theory-ladenness of observation by top-down processes like learning and attention-modulation but this does not influence basic perception as being theory-neutral and cognitively impenetrable (Raftopoulos, 2001). Along similar lines, Carruthers makes an extensive argument for the massive modularity of the mind (Carruthers, 2006) including perception (at least early visual processes) as being implemented as an impenetrable module. Thus, there is still a line of influential representatives in cognitive science who defend the classical view of perception as a module. Our aim is to finally challenge this classical view (alongside others in recent years, e.g. Macpherson, 2012; Wu, 2013) but with a special focus on different types of cognitive penetration.

In the philosophy of mind literature, one of the recent key arguments against cognitive impenetrability of early visual processes has been put forward by MacPherson (2012). She bases her philosophical argument on the experimental results by Delk and Fillenbaum (1965). Delk and Fillenbaum (1965) showed subjects shapes of various objects (typically red ones such as a love-heart shape or lips, and other objects such as a square, a bell or a mushroom) which were cut out from the same orange sheet of paper. Subjects were told to instruct the experimenter to make the color of the background on which the cut-out shapes were placed more yellow or more red until it was the same color as the cut-out shape, so that the objects could no longer be distinguished from the background. The results of the study demonstrated that subjects are more likely to perceive the color of an object as more red if the shape of the object suggests a characteristically red color due to its semantic association (e.g. the object heart) than if the object does not have this semantic association (e.g. a square). This old example can already be used to work out one important clarification: studies of color comparison cannot be explained be arguing that the adjustment of the color shades is a product of concepts or judgments (while the percept remaining unchanged) because we know that fine-grained color comparison is independent from concepts and judgments. The ability to compare two shades of color at one time does not presuppose the ability to re-identify the fine-grained differences of two shades of color in contexts when they do not appear simultaneously. Since colour comparison does not include the ability of re-identification of the type of color, this ability to compare colors is usually taken to be a central example of a non-conceptual ability (Raffman, 1995). Thus, it is implausible to interpret the results of the experiment as relying on either concepts or on judgment because judgments presuppose conceptual representations.
A recent study has provided evidence for the neural underpinnings of the effect originally found by Delk & Fillenbaum. Bannert & Bartels (2013) presented subjects with grey-scale images of typically colored objects (e.g. a banana, a broccoli or a coke can) and demonstrated that the memorized associated color can be decoded from fMRI activity patterns in V1. That is, V1 contains specific color information related to the object even though the sensory bottom-up signal is entirely achromatic. Similar to Delk & Fillenbaum's study but with the higher methodological standards of our days, Levin & Banaji (2006) tested the degree to which background knowledge (and expectations based on it) about the relative skin tone associated with faces of varying races affects the perceived lightness of those faces. Subjects were shown a reference face next to an adjustable face. Their task was to manipulate the adjustable face so that its shading matched that of the reference face as closely as possible. Subjects were free to adjust the luminance of the face up and down as much as they liked. The result was that White faces (with Caucasian features) were consistently judged to be relatively lighter than Black faces (with African features). Again, the underlying cognitive ability is just the comparison of color shades which can plausibly be defined as a non-conceptual ability. Thus, it fits much better into a general epistemology if we accept that this is a case of cognitive penetration of visual experience (in a narrow sense) by higher-level expectations concerning the face-color association anchored in (at least implicit knowledge about) the categories of races. If one wants to

deny cognitive penetration in this case, one basically has to argue that the alleged change in experience is actually only a change in some non-conceptual processes (since we excluded the relevance of concepts) and takes place exclusively in a low-level or a high-level perceptual module.[2]

Why should we accept the face-race study by Levin and Banaji (2006) as a case of cognitive penetration? Here are further arguments that support the acceptance of this example as cases of cognitive penetration given (i) physiological evidences for the modulation of V1 (ii) observations to exclude alternative interpretations and (iii) further studies (Section 3):

(i) a. The neurophysiological connections of the primary visual system with the rest of the brain are such that there are much more feedback connections to primary visual cortex from higher cognitive areas than feed-forward connections to higher cognitive areas (e.g. Salin & Bullier, 1995).

(i) b. The time course of visual processes in V1 and V2 is such that we cannot presuppose simple serial feedforward processing. For example, Kanizsa figures elicit the perception of illusory contours. The temporal dynamics is, unexpectedly, not consistent with V1 firing first and transferring the activation to V2 (Lee & Nugyen, 2001). The activation of V1 caused by illusory contours emerges 100msec after stimulus onset in the superficial layers of V1, and around120–190 msec in the deep layers of V1. However, in V2 the illusory contour response begins earlier, occurring at 70 msec in the superficial layers and at 95 msec in the deep layers. This temporal sequence suggests that the computation of illusory contours involves intercortical interaction, and that early visual processing is likely to be interactive (Lee & Nugyen, 2001).

(ii) We would like to rule out alternative explanations which aim to exclude the relevance of semantic content for early visual processing. Even linguistic labels and basic linguistic categories influence the primary visual system: In the face-race study (Levin & Banaji, 2006) an ambiguous face (concerning racial categories) was seen lighter when it had the label “white” and darker when it was labelled “black”. Furthermore, Winawer et al.(2007)demonstrated the influence of basic semantic categories on perception. They presented Russian and English speakers with color swatches of different shades of blue. The experiment is based on different ways of categorizing shades of “blue” in both languages: Russians lexicalizes thecategorybluewithtwobasiclevelterms:“siniy”fordarkerbluesand“goluboy”for lighter blues while the English have just one basic–level term “blue”. The students were asked to decide as quickly as possible whether a top color exactly matched a color on its left or on its right. While all shades of colors were in the category “blue” for the English, the colors were part of the two different basic categories of “blue” for the Russian speakers. Winawer et al. (2007) found a categorical perception effect only for the Russian speakers, i.e. the Russian – but not the English – had slower reaction times (RTs) on within-category than between-category trials. Further evidences of a top-down influence of linguistic labels or categories on perception are reviewed by Lupyan (2012).

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[2]Wu (2013) also recently argued against cognitive impenetrability by showing that intentions penetrate visual perception. He uses the example of space constancy: the fact that we perceive the world as stable despite the constant change of the retinal image due to eye movements. He reviews the neuroscientific evidence demonstrating the crucial role of motor signals in space constancy and as such how intentional eye-movements can penetrate early vision. He also adds another condition for cognitive penetration: penetrating cognitive contents must serve as informational resource for visual computation to be effective penetration.

Given these evidences we evaluate the possible other defense strategies (for review of defense strategies see: MacPherson, 2012; sec. 3) as coming with inacceptable costs. Therefore, according to an inference to the best explanation, we take the face-race study by Levin & Banaji (2006) to be a case of cognitive penetration in the narrow sense. In the following, we will present more examples from the psychological and neuroscientific literature that are best explained as cases of cognitive penetration (either in a narrow or broad sense) before we start to systematize the different types of penetration of perception.

3. Further empirical evidence for cognitive penetration from neuroscience and psychology

Many forms of visual illusions can be taken as evidence for cognitive penetration of early visual processes by several cognitive factors. For example, apparent motion demonstrates well how expectations are created from the visual context and how they affect basic visual feature perception and processing as early as V1. In apparent motion, two alternately flashing stimuli create the illusion of one moving token (e.g. Vetter et al., 2012). V1 neurons fire on the apparent motion path as if real motion was present, even if these V1 neurons are neither activated bottom-up through the retina nor through lateral interactions (Muckli et al., 2005). That is, the context of flashing stimuli induces the inference of motion in the brain (created by motion area V5; e.g. Vetter et al., 2013) and influences both our perception as well as the firing patterns of V1. That is, V1 neurons on the apparent motion trace fire as if a real moving token was present. Similar contextual effects, and as such the creation of expectations of the incoming sensory information, also happen on the multi-sensory level. Seeing a single light flash simultaneously with two auditory beeps results in the illusory perception of two light flashes (and vice versa, two flashes accompanied by one beep result in the perception of a single flash). Again, this illusory perception is accompanied by increased activation of V1 neurons (and a decrease in the opposite case; Watkins et al., 2006; 2007).
Expectations of our sensory environment can even go as far as hallucinating visual features even if they are not actually there. In a study by Chalk et al. (2010), subjects were implicitly trained to expect certain motion directions as more frequent than others in a dot motion detection task. Subjects demonstrated a bias towards the trained (more likely occurring) motion directions even when no coherent motion was presented (i.e. when dots moved randomly). This shows that expectations acquired by fast statistical learning bias subject's perception of motion even in the absence of coherent motion.

Also more high-level cognitive contents are able to influence visual perception. The following examples are challenging for the claim of cognitive impenetrability since the percept is modified and not just our belief or concept associated with the percept. Although the following examples are not excluding the idea of a very constrained impenetrable primary visual processing module, they clearly show that the perceptual experience is modified by high-level processes. Thus if one wants to maintain the notion of impenetrable primary visual processes, these would be constrained in such a strong way that they are never sufficient to explain the visual percept of a human being. Thus, if one does reject the cases above as ruling out an impenetrable visual module then the following cases still have the consequence that processing in such a module cannot do any relevant work for visual experience. Thus, we need to account for top-down influences when developing an adequate theory of the visual percept in everyday experiences.

For example, Kitayama et al. (2003) provided evidence for possible cultural influences on basic line length judgments, a classical process of early vision. Here, Westerners performed better when line length was judged ignoring the perceptual context (a surrounding box) compared to when a proportional judgment was required that necessitated taking the perceptual context into account. Asians, by contrast, show the opposite performance pattern. The authors of the study suggest that Westerners, due to their more individualistic culture are less influenced by contextual information, whereas Asians, due to their more holistic culture, are influenced by contextual information even in low-level perceptual tasks such as line length comparison. There is also converging neuroimaging evidence supporting this interpretation: Westerners compared to East Asians activate more areas related to object-processing when viewing complex visual scenes (Gutchess et al., 2006), whereas East Asians are more sensitive to incongruencies between foreground objects and the background, an effect also observable in object processing areas (Jenkins et al., 2010).

Anderson et al. (2011) demonstrated elegantly how gossip influences whether a person’s face is perceived or not. Here, images of faces were paired with positive, negative or neutral gossip, i.e. affective social information such as “threw a chair at his classmate”. Under conditions of binocular rivalry (i.e. when one eye is presented with the image of a face and the other eye is presented with the image of a house), faces paired with negative gossip were perceived more frequently than faces paired with neutral or positive gossip. That is, previously learned and socially relevant information biases the perceptual content of visual consciousness. Given that binocular rivalry involves V1 (Lee et al., 2005), this finding indicates that complex high-level information may bias low-level visual processes.

Similarly, the literature of subliminal priming contains many examples of how semantic information, even when presented unconsciously, biases visual perception. When observers are presented with masked stimuli below their individual detection threshold, such that they are never consciously aware of these stimuli, the semantic content or emotional meaning of these subliminal stimuli do nevertheless significantly influence their perceptual experience of a subsequent stimulus that is consciously perceived (e.g. Kouider & Dehaene, 2007).For example, the conscious perception of numerosity in a small set is influenced by subliminally presented primes of Arabic numerals or number sets (Bahrami et al., 2010).

Also emotional information can influence relatively low level visual perception. For example, Murphy and Zajonc (1993) showed that subliminally presented angry or happy faces influence peoples’ perceptual judgment of Chinese characters. Even if unrelated emotional information is presented consciously as a prime, simple visual feature perception is affected. Phelps et al. (2006) demonstrated that the presentation of an emotional face increased subjects’ sensitivity to contrast in a subsequently presented display of simple gratings. The effect of emotion was not just due to enhanced attention, but instead it potentiated the effect of attention. Bocanegra and Zeelenberg (2009) extended these results by showing that the presentation of a fearful face affected also sensitivity to orientation, and that this effect could be an improvement or an impairment of perceptual sensitivity depending on the gratings’ spatial frequency. Similarly, racial biases modulate early electrophysiological signatures of face processing (Ofan, Rubin & Amodio, 2011; Senholzi & Ito, 2013). Also higher level visual perception can be affected by desires and emotions. For example, when judging distance to objects, desired and threating objects are perceived as physically closer than less desirable or disgusting objects (Balcetis & Dunning, 2010; Cole, Balcetis & Dunning, 2013).However, emotional influences may strictly speaking not belong to the category of cognitive penetration but to a separate kind of affective penetration, a point to which we will return later.

All these examples demonstrate that visual perception, particularly those aspects of visual perception that are associated with early visual processes, are substantially influenced by factors such as expectations and context as well as emotional, social and cultural information. What these examples furthermore suggest is that the idea of functionally encapsulated visual processing units is not entirely realistic. In fact, there is much recent evidence that early visual cortex, including V1, is significantly influenced by contextual information and feed-back processing (for a recent review, see Muckli & Petro, 2013). For example, V1 activity has been demonstrated to be influenced by the information content of the visual surround (Smith & Muckli, 2010), by the content of memory even in the absence of a visual stimulus (Harrison & Tong, 2009) and by the content of what is heard or imagined, again in the absence of a visual stimulus (Vetter et al., 2014).

Thus, this recent evidence severely challenges the notion of functionally encapsulated visual processing modules which is the crucial assumption underlying the thesis of cognitive impenetrability. On the basis of an inference to the best explanation, we take cognitive penetration to be a fact. At least we have shown that if one still insists on a very constrained impenetrable module then this is not helpful to explain human visual experience. Thus, we suggest to change perspective: accepting cognitive penetration to explain human visual experience. However, then it becomes very important to distinguish different types of cognitive penetration. When developing our alternative view, we will do so by introducing further examples.

4. Cognitive penetration embedded in a hierarchical four-stage model of perception

The main claim of this paper is that different types of cognitive penetration need to be distinguished depending on the level of perceptual processing on which they take place and depending on which level of processing the penetrating influence comes from. Thus, cognitive penetration should not be considered as an all-or-none phenomenon (i.e. as existing or not), but as an existing and multi-facetted phenomenon.

To this aim, we first propose a perceptual model with four different hierarchical processing levels based on neuroscientific evidence and similar to many other models of visual perception. We do not want to claim that our perceptual model is entirely novel or different from previous models of visual perception, however, we need to embed our thesis of different types of cognitive penetration in a neuroscientifically plausible perceptual model to show how penetration is realized in the functional machinery of the brain.

Let us already mention that our account is compatible with the recent theory of predictive coding (Friston, 2010; Clark, 2012) and can be seen as framework of spelling out the predictive and selective aspects of both bottom-up and top-down processes that constitute object perception. We will discuss the relationship to predictive coding in more detail in Part 6 of the paper.

In our account, the four stages of visual processing may correspond roughly to processing in different brain areas, however, the distinction is an abstract one and we do not assume modularity, only a functional unit with relative independence. There is plenty of evidence that perceptual processes are highly dynamic and the functional boundaries between brain areas are continuous. We rather conceptualize the different stages as dynamic functional processing units. The distinction of stages is nevertheless explanatory fruitful and will be shown to account for cognitive penetration and several perceptual phenomena. The stages are hierarchically organized and the processing result is produced by both bottom-up and by top-down processes.

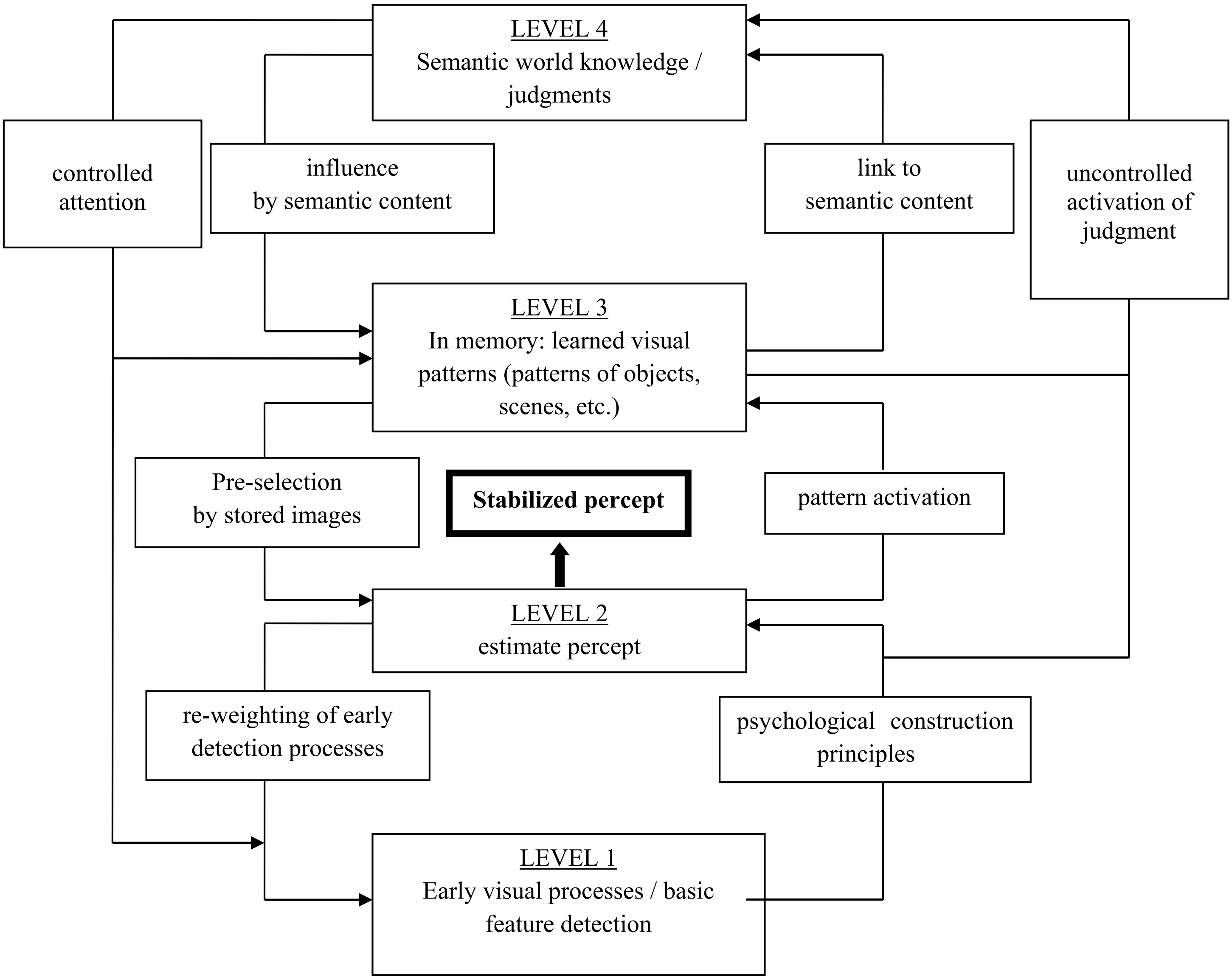

Fig. 1. Schematic diagram of a four-stage hierarchy of perceptual processing.
Note that levels represent dynamic functional units instead of functionally encapsulated modules in the brain. Interactions between stages illustrate the different pathways top-down cognitive penetration or bottom-up sensory penetration can assume.

Stage 1: Basic feature detection based on well-defined principles. Here the basic features of the visual percept are detected through fast, bottom-up processes according to standard psychological construction principles. These processes include the basic visual features as classically processed in early visual areas, such as contrast, luminance, spatial frequency, contours and edges, but also motion and color detection takes place here. This stage may also include the basic processing of a fast feed-forward gist capture as postulated by Lamme and Roelfsema (2000) or Hochstein and Ahissar (2002).Furthermore, subcortical visual processing is also part of this level of processing.

Stage 2: Creation of an estimate percept. Here a preliminary, instable percept is estimated from the outcome of basic feature analysis. It is the first level of feature and multimodal integration into a percept and it develops into a stable percept within the dynamics of the stages (see below). We have to presuppose such a stage of integration as can be illustrated by well-known lesion phenomena, e.g. a lesion in V4 leads to achromatopsia (a percept of seeing objects only in shades of grey), a bilateral damage to V5 lesion leads to akinetopsia which results in a percept without motion perception.

Stage3: Matching with learned visual patterns of scenes and objects. Here the estimate percept is compared to visual templates stored in memory. Stored perceptual patterns or invariant representations are activated and matched against the estimate percept created from low-level features to allow pattern recognition and higher level categorization (for example, face, object or scene categorization).
The famous picture of the Dalmatian dog is an example here: when seeing the image for the first time, most people only perceive an unstructured pattern of black dots on a white background. After a certain time or after seeing a higher resolution of the picture, everybody perceives the Dalmatian dog even in the low-resolution image. Here, a memorized template of a dog modifies the visual perception of a seemingly unstructured noise pattern.[3]

Stage 4: Relation to complex semantic world knowledge. Here, the visual input is associated with higher-level knowledge, such as stored semantic meanings, abstract knowledge and complex beliefs. Associative agnosia is an example here: patients are able to describe features of objects such as color, form, texture or size and copy drawings accurately, but fail to name objects or their proper functions (for an overview of cases of visual associative agnosia, see Capitani et al., 2003). Thus, the deficit of these patients does not concern the typical perception of objects and scenes as such, but the semantic object identification associated with the percept.

It is important to note that all these stages of perceptual processing are highly interconnected and forward and backward loops on all levels influence each other, most frequently neighboring levels but also distant ones. We rely on plenty of evidence in the neuroscientific literature that feed-forward and feed-back connections exist between almost all functional brain areas within and across sensory modalities (e.g. Salin & Bullier, 1995; Driver & Noesselt, 2008). In fact, recent evidence suggests that the brain has much more long-range connections between distant brain areas than previously thought (Markov et al., 2013).Crucially, it is the multi-directional processing along these

[3] Here, the learned visual pattern can be either a specific image token encoded in short-term memory (as the specific image of the Dalmatian dog), or it can be a categorical template or invariant representation that is stored in long-term memory or is even innate (a generalised face template, for example).

connections that results in perceptual experience, creates a stable percept out of the estimate percept and gives rise to different types of bottom-up and top-down influences.

We postulate that top-down effects from a higher to a lower level can be fruitfully described as cognitive penetration as lower levels mainly concerned with processing sensory input are influenced by higher level "cognitive" factors. In contrast, bottom-up influences can be described as "sensory penetration" as higher levels concerned with processing cognitive contents are influenced by sensory information. The latter is a more intuitive notion given the traditional view of basic sensory processing giving rise to a high-level percept. For example, sensory penetration may explain very well distractor effects – the fact that we cannot help being distracted by irrelevant sensory input which often penetrates or interferes with our perception against our will. Given the impenetrability thesis, we will focus on top-down cognitive penetration in this paper.

By using the terms "cognitive" for higher level perceptual processing and "sensory" for low-level perceptual processing we do not want to imply that there is a clear-cut boundary between sensory and cognitive processing. We rather assume a gradient between both types of perceptual processing: lower levels being mainly, but not exclusively, concerned with processing basic features of the sensory input (such as contrast, orientation, color), and higher levels being mainly, but not exclusively, concerned with deriving and storing abstract and generalized cognitive contents (such as rich mental images, general world knowledge or semantic contents). The majority of processing is realized in the many intermediate levels in the hierarchy which send and receive information with different levels of abstraction in either direction, belonging neither to a pure "sensory" nor a pure "cognitive" category.

We postulate that penetration can happen in either direction of the hierarchy and from any level to any other level. Each perceptual experience is the outcome of differing amounts of both sensory and cognitive penetration. Our claim has two consequences: 1. the differences between cognitive and perceptual processes remain relative and gradual without clear-cut boundary. 2. There are several varieties of cognitive or sensory penetration depending on the processing level which is influenced and depending on the processing level where the influence comes from.

We are aware that besides a cognitive and perceptual dimension, an affective dimension can be defined. There are several examples in the literature demonstrating how emotional valence can influence visual perception, exemplifying an influence we would call affective penetration. However, emotions can sometimes be conceptualized as either perceptual (see e.g. Deonna, 2006; Döring, 2007)or cognitive, i.e. as belief or judgment (eg. Solomon, 1993) and represent therefore not a clear case against or in favor of cognitive penetration of visual perception.[4] We believe that affective penetration is a separate case and we will focus on cognitive penetration for the remaining of this paper.[5]

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[4] But we argued independently that emotion recognition can best be analysed as a process of perceiving patterns of characteristic features. This comes with the claim that object recognition and emotion recognition essentially involve the same processes, just dealing with different inputs (see Newen et al. in press).

[5] Further interesting cases of penetration onto visual perception can be the penetration of cognition on action-guided vision. McIntosh & Lashelya (2008) demonstrated that the visual perception of a box and its learned size influences the automatic shaping of the hand for grasping, even if the item has a different size in reality. This is

5. Cognitive penetration as a consequence of mutual influences between perceptual processing levels

In the following, we will explain in more detail how a visual percept arises from the levels of perceptual processing, and how different types of cognitive penetration play a role in the emergence of the percept. With the aid of several examples we will demonstrate that our claim of different types of penetration is justified, how it can explain many perceptual phenomena and how it is supported by neuroscientific evidence.

We will first describe influences between neighboring levels of our model of perception, and then turn to cases of cognitive penetration across several levels. We will also describe cases lying at the extremes of the hierarchy: penetration solely between lower levels and penetration mainly happening on higher levels.

Within our model, the initial visual percept is constructed along constant feed-forward and feed-back loops between stage 1 and 2 until a stable estimate of the percept is reached. Here, low level visual phenomena such as color and contrast constancy and adaptation effects arise. In the next stage, the percept estimate is constantly compared to stored perceptual patterns of stage 3 and in this loop, basic recognition takes place since typically unified and categorized objects are represented at this stage. We suppose that conscious perception is possible at this stage, however, as mentioned earlier, we do not discuss aspects of consciousness in great detail here. In many cases, the percept estimate is influenced by the stored perceptual patterns of stage 3, but there are cases where the estimate percept remains within the loop of levels 1 and 2. For example, the stable perception of a novel, previously unseen object is still possible despite the lack of a learned template.
Many visual illusions happen within the interaction of level 1, 2 and 3. Apparent motion is an example for low-level cognitive penetration emerging through recurrent processing mainly within the loops of level 1 and2. First, at level 1, the apparent motion inducing stimuli are detected by V1, and the dynamics of their appearance is detected in motion area V5. From the dynamics of the onset and offset of stimuli, i.e. from the feed-forward signal from V1 (and possibly by comparing it to learned motion dynamics on level 3) V5 infers motion and, after several iterations, creates a conscious estimated percept of a moving token (level 2). This estimate percept is unstable, because the information from level 1 is incomplete: there is no bottom-up signal from a moving token on the motion trajectory which does exist in real motion. This is why apparent motion is an unstable percept and easily breaks down after long exposure (Anstis & Giaschi, 1985). The estimate percept feeds back to level 1 and informs V1 that there should be a motion token on the apparent motion trace – this gives rise to the spatially specific V1 signal on the apparent motion path (Muckli et al., 2005). Apparent motion can thus be explained as a type of cognitive penetration on the very basic levels of feature perception and serves as an example for extreme low-level cognitive penetration.

The cognitive penetration of object or face shape onto color perception as discussed above (Delk & Fillenbaum, 1965; Levin & Banaji, 2006; Bannert & Bartels, 2013), are cases of cognitive penetration from level 3 onto level 1.Let us describe this for the race-face case (Levin & Banaji, 2006) in detail:

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a case for cognitive penetration of action-guided vision where a memorized image influences grasp programming. For a philosophical discussion of these cases see Nanay (2013).

The perception of the racial shape of a face (Caucasian versus African) activates the stored perceptual patterns of the type of race, and co-activates its associated color (with relevant image patterns on level 3). Therefore, a typically Caucasian face activates a memory pattern associated with the light skin color of a white person and influences, via feed-back, the estimate color percept on level 2. This in turn may boost the processing of luminance and color channels on level 1.Given that the estimate percept is flexible and can be shaped by influences from higher levels, the perception of the color of typically Caucasian faces has a bias towards a lighter color compared to seeing the same skin color in an African shaped face.

Another example for cognitive penetration involves long-term modification of the psychological construction processes which connect levels 1 and 2. The learned memory patterns of level 3 may in some cases influence the construction principles that act on the basic feature analysis in level 1 or the estimate percept in level 2. The Müller-Lyer illusion may be an example here. One explanation for the Müller-Lyer illusion is that growing up in a carpentered environment might determine memory patterns (level 3) of the proportion of lines when they are embedded within adjacent lines of certain angles (e.g. Gregory, 1968; McCauley & Henrich, 2006; Deregowski, 2013). In other words, the flanking lines may elicit an automatic representation of perspective. These memory patterns or perspective representations will be automatically activated when a line is flanked by lines of a certain angle, and the perception of line length is influenced, even if it is a low-level visual feature mainly processed on level 1.The perspective theory is just one possible explanation for the Müller-Lyer illusion, another one is that the gestalt of the flanking lines (or other flanking figures) has differential centers-of-masses inducing the perception of different line lengths (Morgan et al., 1990; Searleman et al., 2005; Bulatov et al., 2011). Whichever explanation one accepts, it is the contextual gestalt perception of the flankers activating certain memory patterns that induces the illusion. In this sense, the Müller-Lyer illusion is rather similar to the effect found by Delk & Fillenbaum (1965)and Levin & Banaji (2006): the abstract representation of object or face shape automatically elicits a certain color association and thus influences color perception of that shape. We therefore regard the Müller-Lyer illusion as an example for cognitive penetrability, in terms of penetration from stored memory patterns on line length perception, rather than an example for cognitive impenetrability as discussed earlier in the literature (Pylyshyn, 1999). We would agree, however, that there is no cognitive penetration caused by the abstract knowledge that the lines are of equal length (e.g. acquired by measuring the lines). That is, the Müller-Lyer illusion is an example for cognitive penetration from level 3 to lower levels, but not for cognitive penetration from abstract world knowledge implemented at level 4: our knowledge that these lines are equally long does not change the percept. But it is an example of a long-term change in the organization of the information processing and may be similar to how culture shapes the perceptual system. As mentioned above, Asians are more sensitive to contextual features than Westerners and several intercultural studies support the view that culture can shape even basic perceptual judgments(for review, see Han & Northoff, 2008).

Moving up to higher processing levels, the loop between stage 3 and 4 puts the recognized patterns into the context of our stored world knowledge: we saw that this connection is interrupted in the case of associative agnosia. High-level associations, beliefs and semantic knowledge are normally tagged to the visual percept. Barsalou argued that semantic knowledge is capable of immediately activating certain memorized images and sensory patterns since according to his view concepts are perceptual symbols (Barsalou,1999).That is, concepts are essentially grounded in simulations of stored images and sensory patterns (Barsalou, 1999; 2003) and the main function of linguistic utterances is to activate top-down influences in the listener. Influences from level 4 onto level 3 may need learning and plasticity, such that our abstract knowledge is tagged correctly to certain memory patterns. For example, associating a name to a new face requires learning, so that upon recognizing the face the associated name is activated, and vice versa, the mentioning of the name activates a representation of the person's face. Thus, recognizing the face of a philosopher in the "School of Athens" is a type of cognitive penetration by constraining the higher levels of perceptual processing. Having previously learned the identity of the face has created a memory pattern that will ease recognition and thus change the process of pre-selection of stored images compared to when the face has never been seen before. The low-level visual features, or the estimate percept of a face, however, are not affected by this knowledge, only the stage of perceptual recognition. We argue that this type of high-level cognitive penetration is qualitatively different from the type of cognitive penetration that occurs in the visual illusions (apparent motion, shape from shading) discussed above: High-level penetration happens when semantic world knowledge influences pattern recognition, whereas low-level penetration happens when contextual cues shape basic visual feature perception.

In the bottom-up direction, it is also possible that basic visual features processed by level 1 involuntarily activate a judgment on higher levels –exemplifying sensory penetration. For example in blindsight patients with damage to V1, the subcortical visual pathways transmit sufficient information to higher processing levels such that visual information can be acted upon without being explicitly recognized (Milner & Goodale, 1995).These patients often deny seeing anything, but perform above chance when asked to decide between two objects or to act upon them (e.g. Weiskrantz, 1996) .

Some cases of cognitive penetration may involve all levels of perceptual processing and may allow penetration of high-level semantic world knowledge down to low-level processing. In subliminal priming, the learned memory patterns of level 3 or more high-level semantic connotations (level 4) are activated briefly through a fast feed-forward sweep caused by the unconscious prime (uncontrolled activation of judgment). The brief activation will activate related semantic information or memory pattern and then influence via feedback the perception of even relatively low level features. So in the case of numerical priming, the unconscious activation of a high-level number representation will bias the more low-level perception of numerosity.
Similarly, identifying the gist of a scene might allow us to quickly identify objects depending on contextual information, particularly in cases of ambiguous or coarse sensory information (Bar, 2007). Similar to priming, the gist of a scene can be quickly categorized via feed-forward sweeps and activates related semantic concepts and memory patterns. Via feed-back, these patterns can help identifying an object depending on the context. For example, within the context of a bathroom scene, an angled L-shaped object can be identified quickly as a hairdryer rather than as a gun. These top-down influences through the activation of memory patterns can also happen cross-modally and may reach the very early levels of visual processing. Listening to characteristic sounds of a scene (i.e. traffic noise from a street scene or talking people from a restaurant scene) causes distinct patterns of activity in early visual cortex even in the absence of any visual input (Vetter, Smith & Muckli, 2014). That is, sounds may activate memory patterns associated with the specific scene, possibly eliciting a mental image of the scene, and then this content-specific information is sent to early visual areas via feed-back connections. Similarly, the memory content of bananas being

typically yellow shapes the activity patterns of early visual cortex even if the actual sensory information is that of a grey banana (Bannert & Bartels, 2013).

Apart from loops between neighboring levels, also loops between more distant levels are possible, sometimes circumventing some of the intermediate stages. For example, controlled and voluntary attention may influence directly which basic features in the percept are attended to and as such attentional feedback may facilitates the detection of specific features, as exemplified in search tasks (Hochstein & Ahissar, 2000). Perceptual learning creates new perceptual patterns on level 3 and is as such able to directly influence stage 1 by the allocation of attentional resources to the relevant features.

Another related phenomenon worth mentioning here is the case of mental imagery. There has been a debate on whether mental imagery is cognitively penetrable or not (Thomas, 2011). Within our model, mental imagery is a good example for cognitive penetration from higher levels onto the estimate percept. Here, no (or unrelated) sensory input arrives bottom-up at level 1, thus the estimate percept on level 2 is instable and highly shaped by the top-down influences from level 3 and 4. For example, by imagining a certain animal, the perceptual pattern for that animal is activated and penetrates the estimate percept. Vice versa, mental imagery can profoundly shape low-level visual perception up to the point when subject perceive objects that are not actually there. Instructing subjects to detect a letter or a face in random dot patterns leads to superstitious perception (Gosselin & Schyns, 2003), a beautiful example of how top-down mental imagery can select random bottom-up sensory information to construct a low-level perceptual experience of non-existing visual patterns.

On the basis of these examples we argue that it is not justified to speak of cognitive penetration as a single type of phenomenon, but that instead different types of penetration should be distinguished depending on which processing level the penetrated content and the penetrating factors arise. In the majority of cases, the final percept is created through recurrent loops and interactions across many perceptual processing levels. As a consequence, there are no isolated processing module giving rise to a particular perceptual content, but this content is created interactively through different types of cognitive and sensory penetration. Another consequence of our account is that it becomes difficult to categorize perceptual contents as purely perceptual or purely cognitive, dissolving a clear-cut perception-cognition boundary.

6. Relevance to other theories of perception

Our account of cognitive penetration is relevant to other theories of perception. We will just mention two of them, but there are several other models that fit within out framework (e.g. Bar, 2007; Gilbert & Sigman, 2007; Summerfield & Egner, 2009).

6.1 Predictive coding

One important theory to mention is the framework of predictive coding. The most recent and theoretically most detailed account of predictive coding has been put forward by Friston (2010) and Clark (2012) while the basic ideas have been developed already earlier going back to Helmholtz

(1860), Sokolov (1960), Gegory (1980) and Mumford (1992; see Clark (2012)and commentaries for an extensive review and the history of these ideas). Predictive coding states that the brain constantly makes a model of the outer word according to Bayesian principles to predict the incoming sensory information. Here, a predictive model is created on most levels of perceptual processing. The predictive information is fed down to lower stages via feed-back connections and influences the processing on these lower levels. In the relevant lower level, the predicted information and the incoming sensory information are compared, and a possible mismatch is extracted as an error signal. This error signal is communicated feed-forward to the higher levels of processing where it corrects and adjusts the predictive model. Via further recurrent loops, a better predictive model is computed and fed down again to the sensory input layer until a minimal error signal is achieved. In this framework, top-down influences play a crucial role as they carry the most important information: the prediction on how the sensory information is likely to be composed. The predictive model itself is shaped by sensory information coming from other modalities, by contextual information, past experiences and information stored in memory, depending on which level of processing the prediction takes place. The purpose of predictive coding lies in the massive reduction of processing effort required to deal with the vast amount of sensory information the brain is constantly confronted with. The wealth of sensory information has to be processed fast and efficiently to allow us to interact with the environment and to guide our actions. Predicting some of this information based on past experience is an efficient way to make processing more efficient and to allow limited processing resources to be allocated to novel and important information. For example, an unpredicted and suddenly appearing stimulus creates surprise and an error signal that guides our attention towards that novel stimulus, while other stimuli are processed with less resources (e.g. leading to phenomena such as inattentional blindness). One of the implications of the theory of predictive coding is that it regards perception as an active and constructive process rather than a passive "recording" process. It also implies that the brain never perceives the world as "blank slate", the brain always has some presuppositions (according to Bayes' theorem) on how the sensory information should be composed. Predictive coding can thus be regarded as an extreme form of cognitive penetration as perception is always substantially coined by other factors, such as contextual cues, multi-modal influences and information from memory. As final consequence, this may mean that we cannot draw a clear line between "raw" sensory information and "constructed" perceptual content anymore which may dissolve the clear separation between our concepts of perception and cognition (Clark, 2012). Our account has the same consequence in that a clear-cut perception–cognition boundary is not justified if one accepts multiple types of cognitive penetration. Furthermore, our account fits very well to the principles of predictive coding, also we assume that, for example, at level 2, recurrent loops of processing lead to a stabilized estimate percept and that feed-forward and feed-back interactions exist between the other levels of processing. What distinguishes predictive coding from our account is that it assumes that top-down influences always carry a predictive component, whereas our account does not necessarily make this assumption.

6.2 The role of concepts in perception

Furthermore, in terms of philosophical models, our account allows to settle the old classical debate on the role of concepts in perception which goes back to the Kantian view that we cannot make any perceptual experience without concepts being involved. In modern times, it is Dretske (1981) who defended the opposite view that sensory experiences never involve concepts (while it is only the judgments based on them that do). The Kantian view received support by McDowell's argument that perceptual experience justifies our judgment, and to play this role perceptual experience must already be conceptual (McDowell,1994). However, this is a non sequitur since it was convincingly argued that states can be justificatory irrespective of whether they are conceptual or non-conceptual (Bermúdez, 1995). To fulfil this role these states have to be representational, i.e. with respect to the states, properties and objects in the world. Bermúdez argued that three criteria are essential for representational states: (i)they should serve as an explanation for the behavior of a cognitive system that is not an automatized reaction. (ii)They should admit the integration of motivational states into these representational states. (iii)They should be structured in a compositional way and allow for misrepresentations (Bermudez, 1995). It is convincing that non-conceptual states are able to fulfil these criteria and thus McDowell loses his main argument for the Kantian view that all percepts are penetrated by concepts. The classical debate which focused on a priori arguments let to an impasse. Our account offers a step forward: on the one hand, it makes clear that there can be perceptual experiences without top-down influences (e.g. an animal or a baby which perceives a puppet without any learned similar images and any concepts at hand); this gives credit to Dretske's view; but if we do have acquired concepts, perceptual experiences often seem to be influenced by top-down processes in the development of a percept because this makes the stabilization of a most likely percept much more efficient (at least in cases of underspecification or ambiguities).This gives some credit to Kant and McDowell. Furthermore, instead of relying on the notoriously unclear notion of a concept[6], our account is able to be much more specific in spelling out the top-down influences in the process of establishing a percept: we rely on stored images (whether they are conceptual or not) but also on semantic knowledge about objects or even on a package of beliefs (mini-theory) that determines our identification of the object. These influences are described by the different types of top-down influences that we analyzed. Therefore, the core of the Dretske versus Kant-McDowell debate can be settled and put into a new research question which we intended to offer a framework for: how can different types of cognitive penetration be distinguished and what are the underlying perceptual mechanisms?

A final worry may come up: Don't we loose perception as a basis for truth if we grant that perception is penetrated all over? We do not think so. To defend this, we should distinguish everyday knowledge and scientific knowledge. Even if cognitive penetration allows only knowledge according to pragmatic standards (usually to a degree that allows us to realize practical aims), this still deserves the status of knowledge. Scientific knowledge needs careful methodological anchoring, especially since we are aware of cognitive penetration. But this does not give us sufficient reason to establish a radical skepticism about finding any truth at all. Knowledge about cognitive penetration in all its varieties can make us more sensitive for theory-driven interpretation of data but there remains a clear anchoring of perception in the sensory input from the world. Thus, we can easily take a relaxed stance denying the myth of sense data (Sellars, 1956) as well as denying metaphysical realism (Putnam, 1987). There remains a lot of room for varieties of realism and truth when accepting our view of cognitive penetration.

[6]Although we have a clear position about the question what it means to possess a concept independent from linguistic abilities (Newen & Bartels, 2007), it is much better to solve the question of cognitive penetration independent from a position on what exactly concepts are and what it means to possess them. We nevertheless are able to characterize in detail different types of cognitive penetration, one of which may be identified as penetration by concepts.

7. Conclusions

In this paper, we focused on the cognitive penetrability of visual perception, particularly on how early visual processes are influenced by contextual expectations and memorized cognitive contents. On the basis of empirical evidence from neuroscience and psychology as well as philosophical arguments, we argue that the postulation of the existence of visual processes being functionally encapsulated, impenetrable and thus independent of what happens elsewhere in the brain (Pylyshyn, 1999) cannot be justified anymore. After arguing that cognitive penetration in a narrow sense exists, we propose a change of the perspective on the phenomena to be studied: since cognitive penetration always takes place, we argue that different types of cognitive penetration need to be distinguished. Cognitive penetration can involve different types of penetrating factors as well as different types of penetrated processes. As a consequence, thinking of cognitive penetration as an all-or-none phenomenon is misleading, and a clear borderline between perception and cognition cannot be assumed. Even if the reader does not buy our whole story we still hope to have changed the debate into a direction which enables a fruitful interaction of empirical research and philosophical theories.

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