Dreams: An Empirical Way to Settle the Discussion between Cognitive and Non-Cognitive Theories of Consciousness

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Abstract

Cognitive theories claim, whereas non-cognitive theories deny, that cognitive access is constitutive of phenomenology.

Evidence in favor of non-cognitive theories has recently been collected by Ned Block and is based on the high capacity of participants in partial-report experiments compared to the capacity of the working memory. In reply, defenders of cognitive theories have searched for alternative interpretations of such results that make visual awareness compatible with the capacity of the working memory; and so the conclusions of such experiments remain controversial.

Instead of entering the debate between alternative interpretations of partial-report experiments, this paper offers an alternative line of research that could settle the discussion between cognitive and non-cognitive theories of consciousness. Here I relate the neural correlates of cognitive access to empirical research into the neurophysiology of dreams; cognitive access seems to depend on the activity of the dorsolateral prefrontal cortex. However, that area is strongly deactivated during sleep; a period when we entertain conscious experiences: dreams.

This approach also avoids the classic objection that consciousness should be inextricably tied to reportability or it would fall outside the realm of science.

1 Cognitive versus Non-Cognitive Theories of Consciousness

Ned Block (1995-2002) famously introduced a conceptual distinction between access consciousness and phenomenal consciousness. A mental state is access conscious if and only if, roughly, its content is available for belief formation and rational control of action. In contrast, a mental state is phenomenally conscious if and only if there is something it is like to be in that state. The conclusions to be derived from Block's conceptual distinction between access and phenomenal consciousness (the latter henceforth, 'phenomenology' or simply 'consciousness') have remained controversial since the publication of his 1995 paper. Is the distinction actually between different properties; in other words, is there access consciousness without phenomenology or phenomenology without access?

In the search for an answer, the debate has recently moved away from the conceptual domain and into the empirical one, and has focused on the possibility of phenomenology without access.

Whereas in his original paper Block mainly made use of thought experiments to motivate the distinction, in more recent literature (Block, 2007, 2011) he deals exclusively with empirical evidence from current research in cognitive science. Block refines the notion of access consciousness to that of *cognitive access* and the question thereby becomes whether the neural basis of phenomenal consciousness can be disentangled "from the neural machinery of the cognitive access that underlies reports of phenomenal consciousness" (Block, 2007, p. 481). *Cognitive theories* give a negative answer; whereas *non-cognitive theories*[1] claim that the two can be disentangled. Block's argument against cognitive theories is based on the performance of participants in partial-report experiments compared to the capacity traditionally attributed to the working memory. In reply, defenders of cognitive theories have searched for alternative interpretations of such results that make visual awareness compatible with the capacity of cognitive access.

Instead of entering the debate between alternative interpretations of partial-report experiments, this paper offers an alternative that could empirically settle the discussion between cognitive and non-cognitive theories of consciousness. My methodology combines research into the neural mechanisms underlying cognitive access and neurophysiological research into sleep. It also avoids a classic objection that consciousness should be inextricably tied to reportability on pain of falling outside the realm of science; a view recently revived in the literature by Cohen and Dennett (2011).

The next section (§2) presents recent advances in our understanding of partial-report experiments. I present the insights gained from Block's argument against the constitutive role of cognitive access in phenomenology, as well as some responses from opponents that purport to show that the results are inconclusive and that alternative routes need to be explored if we want to provide an answer to the question of whether cognitive access is constitutive of phenomenology. Section 3 offers an alternative proposal for an empirical experiment recently presented by Fahrenfort and Lamme to assess the possibility of phenomenology without cognitive access and shows that it begs the question regarding cognitive theories of consciousness. Finally, Section 4 presents and discuss my proposal for empirically settling the debate between cognitive and non-cognitive theories.

For rhetorical reasons, I present the empirical results as evidence against cognitive theories of consciousness and in supports of the claim that phenomenology is independent of cognitive access. The main goal of this paper should, nonetheless, remain clear: to propose a line of research in the debate between cognitive and non-cognitive theories that is an alternative, though complementary, to that of partial-report experiments; one that by-passes their shortcomings although, admittedly, it may have its own limitations. I deal with some of these potential limitations in the sequel.

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1   This terminology is borrowed from Overgaard and Gruennbaum (2012).

2 Does Phenomenology Overflow Cognitive Access?

2.1 The Overflow Argument

Based on Sperling (1960)'s experiment and some more recent results (Landman et al. (2003); Sligte et al. (2008); among others), Ned Block (2007a) argues that the capacity of the memory buffer in which the content of phenomenally conscious states is encoded is greater than that of the system on which reportability depends. On this basis, Block argues that there are phenomenally conscious states whose content we do not access; in other words phenomenology surpasses cognitive access. Roughly, the insight of Block's argument is the following:
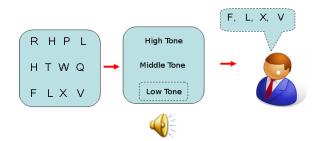

Fig. 1: Sperling's Paradigm

Participants in Sperling's experiment are asked to look at a 3x4 array of letters quickly flashed on a computer screen and to recall them immediately afterwards. This technique, called 'free recall' showed that on average participants were able to recall 4-5 letters out of the 12 they were shown. Already in Sperling's time it was accepted within the scientific community that this was the capacity of the working memory; the memory system that encodes the information we can report on. Sperling believed that all 12 letters were stored in a memory buffer that he called 'iconic memory' for a short period of time, but that this memory faded so rapidly that only 4 or 5 letters could be recalled. He showed this by introducing a second set of conditions into the experiment (see Fig. 1). Participants were presented with the same matrix for the same amount of time, and then heard a pitch. They were to recall the letters in one of the rows, depending on the frequency of the pitch (as shown in Fig. 1). On average, subjects were able to recall more during these cued recall trials than during free recall. Furthermore, by modifying the delay between the presentation of the matrix and the cue, Sperling was able to show that visual stimuli that are not added to working memory are discarded soon after their initial introduction. Block concludes that the best explanation for Sperling's results is that the content of experience is greater than what we have cognitive access to, the former "overflows" the latter, as Block

expresses it, because subjects report having seen all the letters and are able to report the letters when cued, in spite of the fact that the letters were no longer visually present.
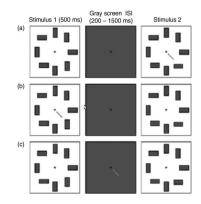

Fig. 2: The paradigm of Landman et al. (2003).

Further support for this idea comes from an experiment by Landman et al. (2003) that combines Sperling's experiment and the paradigm of change blindness. Landman and colleagues presented the subjects with eight rectangles arranged in a circle around a point and asked them to keep looking at the central point. The rectangles could be either horizontally or vertically oriented and were presented to the subjects for 500 ms. The circle of rectangles was replaced by a blank for a given period (200-1500 ms) and after that by another circle of rectangles in which a line (the cue) pointed to one of the rectangles–see Fig. 2. The task was to decide whether the rectangle that was pointed to had changed its orientation (situation (a) in Fig. 2). The result was that, after correcting for guessing using statistical procedures, subjects were able to report correctly on just four of the rectangles; those in the working memory, as we would have expected. Nevertheless, subjects reported having seen all of them. This is the classic "change blindness" result and matches Sperling's result.

In a second part of the experiment, the rectangle was cued in the first presentation of the circle (situation (b) in Fig. 2): the rectangle that may change is already cued before they all disappear. As expected, subjects answered correctly in the vast majority of trials.

The most interesting result emerged from a third experimental set-up (situation (c) in Fig. 2). In this case, the line that cued a rectangle appeared during the blank period, after the rectangles had already disappeared. We know that four of the rectangles are stored in the working memory. The subject tries to compare how the rectangles appear to her before and after the blank; so, if there were no persistent phenomenology in the iconic memory, the subject could not compare how the rectangles appear to her before and after the blank, unless the rectangles were stored in the working memory. We would therefore expect a similar result to that obtained in situation (a). If, on the other hand, there were

persistent phenomenology in the iconic memory, then the orientation of the rectangle could be recalled when the cue was presented and we would expect a result closer to that obtained in (b). The result was that subjects were almost always able to report correctly. Most of the rectangles were phenomenally accessible when cued appropriately. This result seems to support the idea that what is both phenomenal and accessible is that there is a circle of rectangles, whereas what is phenomenal, but in a sense not accessible, is the specific orientation of each of the rectangles. There is a sense in which they are accessible; i.e., they can be accessed if cued appropriately and moreover subjects report having seen all of them.

From these results, Block's suggestion is that "the capacity of phenomenology, or at least the visual phenomenal memory system, is greater than that of the working memory buffer that governs reporting" and he concludes that "...the machinery of phenomenology is at least somewhat different from the machinery of cognitive accessibility" (Block, 2007, p. 489).

2.2 Replies to the Overflow Argument and Recent Evidence

In reply to this argument, defenders of cognitive theories have offered different kinds of rejoinders. Some authors–such as Rosenthal (2007); Brown (2011); Brown and Lau (forthcoming); Kouider et al. (2010); Phillips (2011)–have maintained that the content of phenomenology might not be as rich as some might have thought and that we suffer from some kind of "refrigerator light" illusion: it seems to us that there is a rich phenomenology because whenever we attend to a particular location we find a consciously represented element and we thereby mistakenly assume that it was already conscious before attending. Some proponents of this line of response have claimed, for example, that there is a generic representation of a matrix of alphanumeric characters in Sperling's experiment–or a circle of rectangles in that of Landman et al.–but there is no specific representation as of any particular character–or as of rectangles having particular orientations.

It is controversial whether we can make sense of generic representations of an experience of, say, a rectangle without representing any particular orientation (see Block 2011; Stazicker 2011); but the idea that rich phenomenology is just an illusion can in fact be rescued without appealing to generic phenomenology, by means of fragmentary representations. Whereas before the cue there are unconscious representations of the identity of all the letters–or the orientation of all the rectangles–but only some fragments are represented at the conscious level, when the cue is presented these rich unconscious representations can be brought into consciousness and the subject can report on their content.

Fig. 3: The modification by Kouider et al. of Sperling's paradigm.

The fragmentary representation hypothesis gains some support from an experiment by Kouider et al. (2010). In this variation of Sperling's experiment (Fig. 3) a mask is introduced after the presentation of the array, to avoid retinal persistence of the visual information. The array might contain a rotated letter or a wingding and a free subjective report procedure is introduced into some of the trials, whereby subjects should click on the symbols when they think they were presented in the array. Subjects in this experiment were able to recall fewer elements than those in Sperling's experiments and interestingly, although wingdings were systematically detected, rotated letters were only recognized when they appeared in the cued row. This result is interpreted as supporting the claim that the content of phenomenology might be sparse–constituted by fragments–and that we have the illusion of it being rich.

In reply, Block (2011) argues that the alleged fragmentary nature supposedly demonstrated in the experiment might be due to the low contrast of the stimuli and the mask. Block claims that a better way to avoid retinal persistence while also avoiding disruption to the iconic memory is by using isoluminant stimuli of the type used by Sligte et al. (2008), which are invisible to (color-blind) rods; the main source of retinal persistence. In this kind of experiment, the alleged fragmentariness is much lower. Block suggests that the best explanation for all these results is that conscious content is fragmentary but detailed enough for the task; this would allow us to make sense of a minor illusion effect.

Kouider et al. (2012) offer an alternative explanation of partial reporting by means of partial awareness and unconscious processing in a way that does not require phenomenology to be separated from cognitive access. They distinguish different levels of conscious access in such a way that one

might not access higher levels (say the identity of the letters in Sperling's experiment) but still have access lower levels (fragments of letters). In experimental conditions of perceptual difficulty, perceptual illusions can be explained as a combination of low-level information–fragments–with top-down prior expectation. In response, Block (2012) has argued that the scant empirical evidence we have (Soto et al. (2011)) suggests that unconscious processing is too weak to account for the performance of subjects in the experiments. The discussion remains open and further evidence will be required to settle the debate. Section 4 offers an alternative, but complementary, route to settle the debate.

An independent problem for this approach might be that, as Cohen and Dennett (2011) have recently argued, consciousness should be inextricably tied to reportability; otherwise it would fall outside the realm of science and becoming impossible to falsify. It is not clear to me that this is right, at least insofar as we associate reportability with working memory; as is typical. Be that as it may, in what follows, I will discuss alternative methodologies for research into the possibility of consciousness without cognitive access, which are independent of the research into the role played by unconscious processing in partial-report experiments, and which might falsify the thesis that consciousness entails cognitive access by means of purely empirical evidence.

3 A Case for Non-Cognitive Theories

The philosophical debate between cognitive and non-cognitive theories of consciousness is seen in neuroscience as the debate regarding whether frontal areas are involved in conscious experiences or not. Consider the "Global Workspace" (GWS, Baars (1988)) as a paradigm for cognitive access; then, according to cognitive theories, conscious processes are those that win the competition to activate reverberatory activity in the center of the GWS, thereby maintaining their peripheral sensory excitation until a new coalitions wins out (Dehaene, 2009). Non-cognitive theorists deny this. For example, Fahrenfort and Lamme (2012) have proposed local recurrency in posterior brain areas, which does not involve reverberatory activity in the center of the GWS, as a plausible candidate for the neural correlate of consciousness.

Fahrenfort and Lamme maintain that their hypothesis can be empirically tested. If conscious activity requires only local recurrency, then evidence in favor of consciousness without cognitive access could be obtained by surgically removing the mechanisms of cognitive access–considering the GWS neural model proposed by Dehaene and colleagues mentioned above, this would require breaking the connections from posterior to frontal areas thereby preventing the reverberatory activity in the

center of the GWS. If local recurrency is preserved under these circumstances, then we would have a case of phenomenology without cognitive access. However, as Cohen and Dennett (2011) respond, it is unclear what the reason for accepting this conclusion might be: even if there were local recurrency in the absence of the mechanisms for access, what independent evidence would there be for ascribing consciousness to the subject (taking into account that the subject would deny being conscious)? Either we have independent evidence in favor of local recurrency as the neural mechanism that implements consciousness or there is no non-question begging way to answer this question.

Can we find a case where it is possible, in a non-question begging way, to maintain that there can be consciousness without cognitive access? I claim that we can. The neurophysiology of sleep presents us with a very plausible candidate for such a case and independent research provides reasons for assuming that there are conscious experiences during sleep.

4 A Better Case for Non-Cognitive Theories: Dreams

4.1 The Neural Correlate of Cognitive Access

The first step is to locate the neural correlate of the memory system on which reportability depends; that is, the working memory. Although visual working memory depends on brain activity throughout a widespread network of high-level brain regions (Courtney et al., 1997; Curtis, 2006; Curtis and D'Esposito, 2003), it is widely accepted that the dorsolateral PreFontal Cortex (dlPFC)[2] plays a fundamental role in it (Fuster (2008)).

Already in the nineteen-thirties, Jacobsen (1936) reported that damage to the primate prefrontal cortex caused short-term memory deficits. Soon after, Pribram et al. (1952) identified the part of the prefrontal cortex responsible for such deficits as Brodmann's area 46. Neurons in this area show sustained activity during the delay in visual working memory tasks (Funahashi et al., 1989, 1990, 1991; Fuster and Alexander, 1971; Miller et al., 1996) and dlPFC lesions greatly impair working memory performance (Goldman and Rosvold, 1970; Bauer and Fuster, 1976; Funahashi et al., 1993). More recent transcranial magnetic stimulation (TMS) studies have confirmed that the dlPFC is crucial for maintaining working memory in humans as well (Oliveri et al., 2001; Turatto et al., 2004).

Particularly revealing for assessing the relation between cognitive access and the activity of the dlPFC is the study presented in Lau and Passingham (2006). Lau and Passingham's discrimination task with metacontrast masking allowed them to identify two conditions in which subjects differ in their

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2   The dlPFC is an area in the primate brain roughly equivalent to Brodmann's areas 9 and 46. As it will be clear, the relevant part for the discussion to follow is Brodmann's area 46.

subjective reporting of consciousness–whether they have seen the stimuli or are just guessing–while they show identical objective discrimination ability. Subjects in the experiment are presented with one of two possible stimuli: either a white square or a white diamond on a black background. A metacontrast mask–a mask (a visual stimulus) that shares a contour with the stimuli (the stimuli on which subjects are to report) leading to a reduction in perceived brightness and to degraded perception of the spatial shape of the target (Haynes and Rees (2003))–is presented after a short variable period of time called the 'stimulus onset asynchrony' (SOA). The mask overlaps with part of the contour of both possible stimuli but it does not overlap with any of them spatially, as shown in Figure 4 (a).
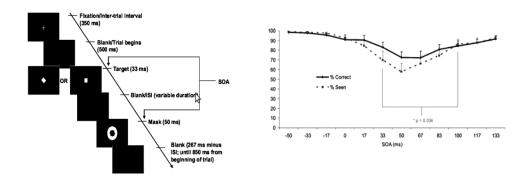

Fig. 4: Lau & Passingham's Experiment (Lau and Passingham, 2006)

a) Experimental Set up

b) Results: performance capacity (% correct) vs. perceptual certainty (% seen)

After the presentation of the target and the mask, subjects have to: i) decide whether the target stimulus was a diamond or a square; and ii) indicate whether they actually saw the target or were simply guessing in the previous task. The first question attempts to measure the objective performance capacity of the subjects: how good they are at identifying the target stimulus. The second question is intended to measure their level of confidence in the identification task they just performed: how confident they are of having seen the stimulus. The authors call this the 'perceptual certainty' of the subjects; a property that clearly requires cognitive access.

The results of the experiment as a function of the SOA are presented in Figure 4 (b). The most interesting finding is that we can identify two conditions under which the performance capacity of the subjects is the same, but their perceptual certainty differs. Whereas in one case (short SOA) subjects tend to report having guessed when they are asked about the identity of the stimulus, in the other (long SOA), subjects are fairly confident of having seen it. This result clearly suggests a difference in the

cognitive access subjects have to the content of their states between the two conditions. After observing this result, Lau and Passingham performed fMRI on the subjects of the experiment and compared their brain activity under the two different conditions. The study revealed that the condition where the subjects tend to report having seen the stimulus–hence, the condition in which subjects tend to have cognitive access to the perceptual information–is associated with a significant increase in dlPFC activity (Brodmann's area 46), indicating that this area is responsible for cognitive access.

4.1.1 Objections to the relation between the dlPFC and cognitive access

Before moving on to the neurophysiological response of the human brain during sleep, I would like to discuss some ways in which one might try to resist the relation between cognitive access and the dlPFC. As we have seen, there is a significant amount of evidence relating working memory to dlPFC activity; but do cognitive theorists have to accept the connection between working memory and cognitive access?

In reply to the preceding question, it should be noted that the experiment by Lau and Passingham does not mention working memory but rather studies the mechanisms of cognitive access and whether subjects are able to report having seen the stimulus. One might try to resist the interpretation of the results offered by Lau and Passingham, and maintain that it is possible that dlPFC activation reflects a second-order judgment: a confidence judgment regarding the categorical identity of the stimulus rather than a direct report of the subject's state (see Ivanowich, 2013). Empirical evidence in favor of this interpretation might be founded in the experiments performed by Heekeren et al. (2004), where subjects undergoing fMRI were asked to decide whether an image presented on a screen was a house or a face. Heekeren and colleagues found that activity within the dlPFC is greater during easy decisions than during difficult ones, for its level covaries with the difference signal between face-selective and house-selective regions in the ventral temporal cortex. Based on this result, they conclude that the dlPFC appears to compare the outputs from lower-level sensory regions and uses a subtraction operation to compute perceptual judgments about the identity of the stimulus. One might suggest, following Heekeren et al., that the increase in dlPFC activity recorded by Lau and Passingham reflects a confidence judgment about the categorical identity of the stimulus, where the function of the dlPFC is to decide what the subject is seeing on the basis of the strength of the responses to sensory information. However, it is important to note, first of all, that the particular area identified by Heekeren et al. is the left posterior dlPFC corresponding to Brodmann's areas 8/9 and not 46. What is more, this interpretation does not seem adequate for the results obtained by Lau and Passingham. In the

experiments by Heekeren et al., activity in the left posterior dlPFC correlated with the difficulty of the task; but in the experiment by Lau and Passingham, the task is not more difficult in the long-SOA condition than in the short-SOA one, as shown by the fact that subject's performance capacity is the same. This suggests that the "strength of the responses of sensory information" is the same–otherwise we would expect a variation in subject performance, as happens when we modify the SOA–and, therefore, that the activity of the dlPFC does not seem to correspond to a "more difficult" decision judgment.

Let me now comment on the assumptions regarding the relation between working memory and cognitive access. Working memory is typically considered as the mechanism responsible for cognitive access. Cowan (2005), for example, while admitting that definition of working memory may differ (see Miyake and Shah (1999)), introduces it in a broad but (fairly) uncontroversial way as:

> [...]the retention of information in a temporarily accessible form, through all available mental processing mechanisms.[...] For some theorists, but not others, W[orking]M[emory] includes the ability to manipulate the information being held in mind. (ibid. p. 155)

If we think of cognitive access as the mechanisms that make information available for other processes (including reporting), then the connection between cognitive access and working memory is straightforward. The devil might, however, be in the details; so it is worth considering them. The most widely accepted and empirically supported cognitive theory at the neurological level is the GWS theory (Baars, 1988; Dehaene, 2009), so I will focus on the relation between the GWS theory and working memory.

According to the GWS theory, the information encoded in the GWS is broadcasted to a multitude of unconscious cognitive brain processes and so is available to them. Considered as a cognitive theory of consciousness, it is proposed that the contents of the GWS correspond to what we are conscious of. Leaving aside the results of Lau and Passingham, one might accept that the dlPFC plays a fundamental role in working memory but resist recognizing its role in the GWS, by dissociating these two theoretical postulates. This is the line of argument explored by Shanahan and Baars (2007) in reply to the argument of Block (2007a). The former authors argue that Block conflates working memory and the GWS and stress that contemporary elaborations of the GWS focus on the neurological basis for this postulated workspace, emphasizing the relevance of the findings by Dehaene and colleagues (see for example Dehaene et al. (1998); Dehaene and Naccache (2001); Dehaene and Changeux (2004); Dehaene (2009)), who suggest that conscious visual experiences require large-scale re-entrant interaction between the posterior visual cortex and frontoparietal regions. A pattern of

activation "is globally disseminated, or broadcast, when it is propagated by this white matter infrastructure, and thereby comes to exercise widespread influence in the brain." (Shanahan and Baars, 2007, p. 525).

If one can make a distinction between presence in the GWS (corresponding to conscious processes) and retention in the short-term buffer of the working memory (which would correspond to unconscious processes), then the following alternative characterization of the partial-report experiments would be available:

> The overall pattern of information flow alternates episodes of broadcast with bursts of competition for workspace access, and the typical duration of discrete episodes of broadcast is on the 100 msec scale.[...] Information pertaining to the initial visual object gestalt in its entirety is broadcast at the time of presentation for one or more 100 msec broadcast cycles. As a consequence of broadcast, this information can influence widespread local brain processes involved in memory---both short-term and long-term. Subsequently, following some retrieval cue, a detailed memory of a portion of the original scene is recalled from the relevant part of short-term memory and is broadcast, enabling (with the help of many other brain processes) a verbal report. Thanks to this process of retrieval and report, or perhaps because of subsequent activity, or merely due to the time that has elapsed, the fragile contents of the short-term memory are degraded and a good deal of information about the original visual stimulus is lost. So no exhaustive subsequent reports detailing the shapes and orientations of specific objects in the scene are possible. But post-hoc partial reports can be retrieved with very high accuracy.[...] Over multiple trials the entire 12-object Sperling array can be accurately reported, always with a reported phenomenal experience of the retrieved item. Moreover, a general impression of the original visual stimulus is retained in short-term memory. If later evoked, this information can still be broadcast, facilitating a verbal report about the overall arrangement of objects in the scene. (ibid. p. 525)

If this were right, then working memory mechanisms would be independent of GWS mechanisms; Shanahan and Baars maintain that Block is missing this possibility. In this case, although partial-report experiments might show that there are phenomenally conscious states outside the working memory, defenders of cognitive theories have nothing to fear from this for it has not been shown that there is phenomenology outside the GWS. However, this reply seems to be incorrect. In the first place, as Block (2007b) rejoins, there is no such misidentification between working memory and the GWS; at the most it is merely a terminological disagreement. Block notes that according to most

models of working memory, three components are distinguished (Cowan, 2005): the short-term memory–mentioned by Shanahan and Baars; attentional mechanisms responsible for broadcasting perceptual and short-term memory contents; and what is broadcasted in the GWS. The disagreement between Block, on the one hand, and Shanahan and Baars, on the other, concerns what they refer to by the term 'working memory': whereas Block uses the term to refer to what is broadcasted in the GWS, Shanahan and Baars clearly reserve it for the short-term memory. The key to settling the discussion lies in which component is the bottleneck in the working memory, and as Block notes: "[t]he bottleneck of working memory on any definition I have seen, including that of Shanahan & Baars, is the capacity of the global workspace". If this is the case, then Block's argument is sound, at least insofar as the discussion with Shanahan and Baars is concerned, for it is precisely the capacity of the GWS that limits our reporting capacities.

Moreover, Sligte et al. (2010) have found a correlation between the level of activity in the dlPFC and the capacity of the working memory. Considering that the GWS is the limiting component in the capacity of the working memory, this seems to relate the dlPFC and the GWS. But, for my current purposes, showing the fundamental role of the dlPFC in the GWS is even more straightforward if we look into the empirical evidence that supports the plausible neurological basis for the hypothesized global workspace–what Dehaene and his collegues call 'the global neuronal workspace' (Dehaene 2009; Dehaene et al. 1998). Dehaene and colleagues explicitly appeal to the dlPFC as one of the fundamental neural mechanisms that implement the GWS:

Physiological and behavioral studies in both humans and monkeys suggest that this ability to maintain information on-line independently of the stimulus presence depends on a working memory system associated with *dorsolateral prefrontal regions* (Fuster, 1989[2008]; Goldman-Rakic, 1987). By this argument, then, the working memory system made available by prefrontal circuitry must be tightly related to the durable maintenance of information in consciousness (e.g. Fuster, 1989[2008]; Kosslyn & Koenig, 1992; Posner, 1994). (Dehaene and Naccache, 2001, p. 10, my emphasis)

In the GWS model, Dehaene and Naccache (see also Dehaene and Changeux (2004)) require that neurons that contribute to the GWS be distributed in at least five categories (high-level perceptual, motor, long-term memory, evaluative and attentional networks). In spite of their spatial separation, those neurons should "enter into coherent self-sustained activation patterns", which in turn requires tight interconnection via long axons. These criteria, as they note, suggest that the dlPFC, the anterior cingulate and areas interconnected to them play a major role in the GWS. Considering, for example, long-distance connectivity, Dehaene et al. (1998) maintain that long-range connections within the

cortex mostly originate from pyramidal cells of layers 2 and 3:

> This suggests that the extent to which an area contributes to the global workspace might be simply related to the fraction of its pyramidal neurons that belong to layers 2 and 3. Those layers, though present throughout the cortex, are particularly thick in *dorsolateral prefrontal* and inferior parietal cortical structures. A simple prediction, then, is that the activity of those layers may be tightly correlated with consciousness. (Dehaene and Naccache, 2001, p. 26, my emphasis)

Further evidence from research into monkeys is presented based on studies by Goldman-Rakic (1988) which describe:

> … a dense network of long-distance reciprocal connections linking *dorsolateral PFC* with premotor, superior temporal, inferior parietal, anterior and posterior cingulate cortices as well as deeper structures including the neostriatum, parahippocampal formation, and thalamus. This connectivity pattern, which is probably also present in humans, provides a plausible substrate for fast communication amongst the five categories of processors that we postulated contribute primarily to the conscious workspace. (Dehaene and Naccache, 2001, p. 26, my emphasis)

The fundamental role of the dlPCF in the interconnection required for the GWS can be seen very clearly in the anatomical substrate they propose for the GWS (ibid. p. 27) reproduced in Fig. 4.
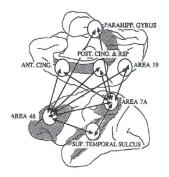

Fig. 4 Proposed anatomical substrate of the GWS by Deahene and Naccache.

Taking into account all these considerations, there seems to be very good evidence to support the claim that the dlPFC plays a fundamental role in cognitive access. Cognitive theories would therefore be jeopardized if there is a condition under which dlPFC activity is compromised, but such that we undergo conscious experiences. In the next subsection I show that the dlPFC is in fact highly deactivated during the conscious experiences we have during sleep: dreams.

4.2 The Neurophysiology of the REM Sleep Phase

Human sleep can be decomposed into two phases depending on whether there are rapid eye movements (the REM phase) or not (the NREM phase).[3] It is well known that in both phases there is a global reduction in metabolic activity and blood flow in the brain, compared to resting wakefulness. For example, positron emission tomography (PET) studies (Braun et al. (1997)) have shown that the decrease can reach 40% during the NREM phase. At the cortical level, activation is reduced in the orbitofrontal and anterior cingulate and also in the dlPFC–Broadmann area 46 (See Braun et al. (1997, table 1 p. 1177)).

There is general agreement that we dream, though most surely not exclusively, during the REM phase. In this phase, some areas are even more active than during wakefulness; especially the limbic areas. In the cortex, areas that receive strong inputs from the amygdala, such as the anterior cingulate and the parietal lobe, are also activated (Maquet et al. (1996, Table 1, p. 164)); this aids in explaining the highly emotional component of dreams (Tononi (2009)). In contrast, the rest of the parietal cortex, the precuneus and the posterior cingulate are relatively inactive (Braun et al. (1997, Table 2, p. 1178)). More interestingly for my present purposes, there is a selective deactivation (compared with during wakefulness) of the dlPFC (Braun et al. (1997); Maquet et al. (1996, 2005); Muzur et al. (2002)). All of these regional activations and deactivations are consistent with the differences in mental states between sleep and wakefulness (Schwarz and Maquet (2002); Tononi (2009)). Taking into account the role of the dlPFC in cognitive access, these results suggest that we lack cognitive access during the REM phase of sleep as it does not seem plausible that another brain area plays the role of dlPFC in cognitive access during sleep (Sebastian (2013)). However, we dream during this phase; if subjects were wakened from this phase of sleep and asked whether they have dreamed, they reply positively at least 80% of the time (Tononi (2009)). And dreams are conscious experiences, aren't they?

In the next section I consider two possible objections that the defender of cognitive theories might raise, and I offer a response.

4.3 Objections

4.3.1 Are dreams conscious?

It is widely accepted that dreams are conscious experiences. This view has been explicitly endorsed, in the philosophical field by, among others, Kant, Russell, Moore, and Freud (Malcolm (1959, p. 4)) and most contemporary philosophers working on dreams also hold it (Ichikawa and Sosa

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3   A more fine-grained categorization of sleep can be established by attending to EEG, EOG, and EMG patterns and dividing NREM into four different stages. See Tononi (2009) for details.

(2009); Ichikawa (2009); Metzinger (2003, 2009); Revonsuo (2006); Sosa (2005)).

The view that dreams are conscious experiences has famously been rejected by Malcolm (1959), who maintains that it leads to conceptual incoherence "...the notion of a dream as an occurrence that is logically independent of the sleeper's waking impression has no clear sense." (op. cit., p. 70). There is no reason, Malcolm holds, to believe the reports given by wakened subjects, for there is no way to verify them: they could be cases of false memories. It could be that processes during the REM phase are all non-conscious, that on awakening the content of our memory becomes conscious and that we confabulate its being conscious episodes. In a similar vein, Dennett (1976) has defended a skeptical position according to which, before establishing whether dreams are conscious we need an empirical theory of dreams and that it is an: "open, and theoretical question whether dreams fall inside or outside the boundary of experience" (op. cit., p. 170-171).

This form of skepticism about dreams being phenomenally conscious experiences rests on the fact that access to dreams is retrospective; in other words, we recall the content of the dream when we are wakened, and a reason for trusting such reports is missing. There are cases, however, in which some people are aware that they are dreaming: lucid dreams. During lucid dreams, the dreamer is able to act deliberately upon reflection and even remember the circumstances of normal life. Lucid dreams have been reported since Aristotle; however, many have had their doubts about the reality of such episodes. For example, Dennett endorses this skepticism; he considers that the report of lucid dreams is consistent with the hypothesis that dreams are unconscious episodes and that the subject is dreaming that they are aware that they are dreaming. The empirical evidence suggests, nonetheless, that Dennett's hypothesis is wrong.

The movement of all skeletal muscle groups except those that govern eye movements and breathing is profoundly inhibited during REM sleep (LaBerge (2000)) making it very difficult to collect evidence in favor of lucid dreams beyond subjects' reports upon wakening. Fortunately, Rowarg et al. (1962) showed that some of the eye movements that occur during REM sleep correspond to the reported direction of the dreamer's gaze. Based on this discovery, LaBerge et al. (1981) provided evidence in favor of lucid dreams. They trained subjects to have lucid dreams and in an experiment asked them to make distinctive patterns of voluntary eye movements when they realized they were dreaming. These prearranged eye movement signals were recorded by a polygraph during REM, proving that the subjects had indeed been lucid during uninterrupted REM sleep. Furthermore, LaBerge and Dement (1982) recorded lucid dreamers who were asked to either hold their breath or breath rapidly (in their lucid dreams), marking the interval of altered respiration with eye movement signals. The subjects reported having accomplished the tasks as agreed a total of nine times, and in every case,

a judge was able to correctly predict, on the basis of the polygraph recordings, which of the two patterns had been executed. These results have been replicated at other laboratories–see LaBerge (1988) for a review. Experiments to study lucid dreams provide evidence that we have conscious experiences during sleep, and give us the opportunity to record reports to that effect. The main reason for skepticism appears to have dissolved: there are conscious dreams. But what happens to dlPFC activity during lucid dreams?

Dreams are characterized by, among other things, reduced voluntary control and reflective thought; characteristics that fit well with the independent hypothesis that the dlPFC is also involved in volitional control and self-monitoring (Fuster (2008)). For this reason, reactivation of the dlPFC has been hypothesized by several authors (Hobson et al. (2000); Kahn and Hobson (2005); Tononi (2009)). Furthermore, lucid dreamers seem to be making a report (via eye movements) on the basis of their experience, which would require cognitive access to them. Now, if the dlPFC plays a fundamental role in cognitive access, as I have been arguing, an increase in its activity during lucid dreams is to be expected and would further support my claim. Preliminary empirical evidence for this hypothesis has been obtained via several studies. For example, Wehrle et al. (2005) and Wehrle et al. (2007), where fMRI was used to study brain region activation during lucid dreams, show that in lucid dreams not only frontal but also temporal and occipital regions are highly activated in comparison to non-lucid dreams. Voss et al. (2009) shows that lucid dreaming by trained participants is associated with increased electroencephalography (EEG) power, especially in the 40-Hz range, over frontal regions. Finally, Dresler et al. (2012) have published neural correlates of lucid dreams obtained from contrasting lucid and non-lucid REM sleep. Not surprisingly, the dlPFC (Brodmann's area 46) is among the areas in which a significant increase in activity is recorded (see Table 1, p. 1019).

Taking these considerations into account, one can still try to resist my reasoning by maintaining that we have conscious experiences during lucid dreams but not during ordinary dreams; after all, although the dlPFC is highly deactivated during ordinary dreams, this is not the case during lucid dreams. My guess is that most defenders of cognitive theories of consciousness would abandon ship if they had to perform this kind of maneuver, denying that ordinary dreams are conscious experiences in contrast to lucid dreams. Be that as it may, evidence against this view can be found in experiments where subjects, whose eye movements are monitored during sleep, are wakened during REM sleep and asked to report their dreams. A correlation between the movement of the eyes and the movements required to motorize the scenes reported from the dreams can be found if scenes that require a specific control of the gaze are selected (Dement and Kleitman, 1957; Roffwarg et al., 1962). For example, in an experiment by Dement and Kleitman (1957), a sleeper looked up and down during REM sleep

followed by his report that he dreamed of climbing up a series of ladders looking up and down as he climbed. Similar results have been obtained in studies of REM sleep behavior disorder (RBD). This condition is defined by Schenck and Mahowald (2002, p. 120) as "a multifaceted parasomnia involving REM sleep and the motor system in which there is problematic behavioral release that is usually experienced by the individual as enactment of distinctly altered, unpleasant, and combative dreams." RBD is characterized by a loss of muscle atonia (paralysis) during the REM phase and Schenck and Mahowald mention that dream enactment (including talking, laughing, yelling, swearing, gesturing, reaching, grabbing, arm flailing, punching, kicking, sitting, jumping out of bed, crawling, and running) was present in 87% of the cases in a study that included 96 subjects. In the same percentage of the cases, subjects reported "more vivid, intense, action-filled, and violent dreams coincident with the onset of RBD, and were often experienced as severe nightmares. Fear and anger were usually present during dreams of being chased or attacked by unfamiliar people, animals or insects." (ibid p. 124). Especially relevant for my current purposes is the study performed by Leclair-Visonneau et al. (2010) with RBD patients. Leclair-Visonneau and colleagues showed that when rapid eye movements accompanied goal-oriented motor behavior (for example climbing a ladder, grabbing a fictive object or hand greetings) in subjects who suffered from RBD, the great majority were directed towards the action of the patient–same plane and direction–suggesting that, when present, rapid eye movements imitate the scanning of the dream scene.

However, the most conclusive evidence, I think, comes from neural decoding. The difficulty of experimentally controlling spontaneous dream activity has made it very difficult to provide a direct demonstration of dream contents using neuroimaging methods. But surprising results has been obtained very recently. The first (preliminary) evidence that specific contents of REM dreaming can be visualized by neuroimaging was provided by Dresler et al. (2011) in a study with lucid dreamers. In that study, the authors were able to measure neural activity–by fMRI and near-infrared spectroscopy– related to dreamed hand movements during lucid dreams using eye signals as temporal markers. More impressive are the neural decoding results just presented in Science by Horikawa et al. (2013). Horikawa and colleagues have used machine learning models to predict the contents of visual imagery in dreams by revealing links between fMRI patterns and verbal reports with the help of image and lexical databases. In order to collect as many reports as possible by repeating awakenings, they concentrated on visual imagery experienced during the sleep-onset period–stages 1 and 2 of the NREM phase–for which studies have shown that reports of dreams are of the same frequency, length and content as those in the REM phase (Foulkes and Vogel, 1965; Oudiette et al., 2012; Stickgold et al., 2000; Vogel et al., 1972). Using lexical databases, they analyzed dream reports and created systematic

labels for visual content; they used natural images from image databases to train the decoders. The brain activity of the sleeping subjects were recorded by fMRI and simultaneously by polysomnography. Subjects were wakened during stage 1 or 2 of the NREM phase and asked to *freely describe their dreamed visual experiences*. The words in the reports describing visual objects or scenes were extracted; for example, in one case they present, the subject reports: "Yes, well I saw a person. Yes. What it was...It was something like a scene that I hid a key in a place between a chair and a bed and someone took it" (ibid. p. 3), and so the key, the person, the bed and the chair were the target objects to be identified. For this purpose, the fMRI data immediately before awakening was used as an input for the decoders. In these conditions, decoders were able to accurately detect, classify and identify the visual objects and scenes. It does not seem plausible, given all the evidence, that the high visual cortical patterns they are decoding correspond to unconscious processes–we cannot freely report unconscious information and subjects claim to report the content of their visual experiences. So, this result seems to "demonstrate that specific visual experience during sleep is represented by brain activity patterns shared by stimulus perception, providing a means to uncover subjective contents of dreaming using objective neural measurement." (ibid. p. 639).

4.3.2 Are dreams sparse?

Another line of response might try to exploit the fact there is some remaining activity in the dlPFC during sleep: although during the REM phase the dlPFC is highly deactivated, this does not mean that there is no activity at all. It seems reasonable to think that cognitive access is not a matter of all or nothing, but that there might be degrees of access. In that case, insofar as there is some activity, there is room for claiming that, diminished though it might be, there is still some cognitive access remaining and therefore room for conscious experiences during sleep.

The only way I can make sense of the idea of degrees of access is in terms of the richness of the content accessed. When there is a lower degree of access, we would be aware of fewer details; that is to say, the content accessed is sparser: we can report fewer details. Such an understanding is consistent with the correlation already mentioned between the level of dlPFC activity and the capacity of the working memory (Sligte et al., 2010).

This response is incompatible with some models of dreaming. For example, philosophers such as Revonsuo (2006) and Windt (2010) have defended models of dreaming according to which dreams are immersive simulations of the sensory-perceptual world that functionally aim at mimicking it. If that were the case, dreams would be as rich as waking experience. Revonsuo, for example, thinks that "there is nothing in the experience itself, in the actual qualitative character of the experience, that

necessarily distinguishes the dream experience from a corresponding perceptual experience in the waking state" (Revonsuo, 2006, p. 82; also quoted by Windt 2010, p. 298). But these ideas are controversial and defenders of cognitive theories might dispute them. Nonetheless, the richness of our dream experiences is stressed by dream researchers, based on subject reports (see, for example, Hobson et al. (2000)). This richness is demonstrated in quantitative studies of dream content. Domhoff (1996), for example, presents an impressive amount of data following the methodology of content analysis initiated by Hall and Van de Castle (1966). Studies based on dream reports of more that 500 American college students show that 12% of all the actions explicitly reported are visual. This result is very significant considering that coding a "visual action" for the analysis requires the explicit appearance of a word such as 'see,' 'notice,' 'read,' 'watch,' 'peek,' 'glance,' 'view,' 'inspect,' or 'distinguish.' (Domhoff (1996, p. 239)). For example, the following report seems to suggest a rich visual experience:

In the beginning of this dream I was in the back of a large open truck with a bunch of other boys. The time is winter and a group of students and myself are on a field trip. The instructor is telling us about the formation of sand dunes and snow drifts as we walk through the snow. We all have a drawing board and are making a drawing of the areas he tells us about. The lecture then seems to get more artistic than scientific as the beauty of the drifts, trees, and few buildings is pointed out. I remember I was making my drawing with a Bic pen just like the one I am using on this report. I tried to show the way the snow looked as it formed little clouds at the lips of the snow banks as it blew. The ones we were seeing were in beautiful pastels of red, green, and blue. The instructor also pointed out the beauty of the noise of the wind. I made a slight whistle that sounded much like it, and someone else did the same. Just before I awakened, the instructor told us about a canoe that was awarded to the student at Yale who could make the best academic recovery and hold it for a month. (ibid. p. 288)

However a unique visual action is coded for "seeing the little clouds of snow" (ibid. p. 290).

One might, nonetheless, suggest that it may be the case that the phenomenology of dreams is much less rich than the phenomenology of waking experience; and that we confabulate the phenomenological richness of our dreams upon wakening (Weisberg (2013)): a confabulation that is reflected in dream reports. It might be the case that our dream experiences are sparse and that we enrich our conscious memory of dreams beyond what was present in the actual event.

The possibility of an "enrichment of conscious memory" is an open possibility that raises interesting methodological issues for any post-presentational report, and not only for reports about the content of dreams. Doubts in this respect might be dissipated by future developments in neural

decoding techniques. Leaving such issues aside for the moment, the defender of cognitive theories faces further problems if they pursue this route. If the level of dlPFC activity were used as an indicator of the capacity of the working memory, then, given the low level of dlPFC activity during REM sleep, the content of our dreams would have to be dramatically sparser than the content of our waking experience. Now, the real problem is that defenders of cognitive theories have to make this kind of response consistent with their explanation of the results of partial-report experiments in reply to the overflow argument where, as we have seen, they maintain that the content of waking experience is already sparser than we think. The content of our dreams would be so sparse and our dream reports so confabulatory that it would be difficult to make sense of findings such as those presented by Horikawa et al. (2013); especially if similar results are obtained in REM sleep decoding, as we should expect considering the similarities in dream reports already mentioned between sleep-onset and REM periods and the estimates of brain activity in high visual areas made by comparing NREM, REM and waking experiences (Braun et al., 1997; Maquet et al., 1996; Maquet et al., 2005; Muzur et al., 2002). I fail to see any room for the possibility of the content of our dreams being as sparse as would be required to make all the observations compatible.

5 Conclusions and Future Lines of Research

My aim in this paper has been to present the study of dreams as an alternative way to examine the relation between consciousness and cognitive access.

Further experiments are required to assess the role of the dlPFC in cognitive access and the meaning of its deactivation during REM sleep. For example, interesting results would be obtained by comparing an individual's levels of dlPFC activity during REM sleep dreams and in metacontrast masking experiments. Moreover, the new techniques for the neural decoding of dreams would help to assess the richness of our dreams. However, the current state of affairs suggests that: i) cognitive access depends on the dlPFC; and ii) the dlPFC does not perform its function during REM sleep. Hence, the most favorable hypothesis is that cognitive access is not required for consciousness.

I do not claim that studies of dreams will offer the last word in the debate between cognitive and non-cognitive theories of consciousness, but they can certainly complement and reinforce other arguments, such as Block's overflow argument.[4]

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