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From non-conscious processing to conscious events: a minimalist approach

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Abstract

The minimalist approach that we develop here is a framework that allows to appreciate how non-conscious processing and conscious contents shape human cognition, broadly defined. It is composed of three simple principles. First, cognitive processes are inherently non-conscious, while their inputs and (interim) outputs may be consciously experienced. Second, non-conscious processes and elements of the cognitive architecture prioritize information for conscious experiences. Third, conscious events are composed of series of conscious contents and non-conscious processes, with increased duration leading to more opportunity for processing. The narrowness of conscious experiences is conceptualized here as a solution to the problem of channeling the plethora of non-conscious processes into action and communication processes that are largely serial. The framework highlights the importance of prioritization for consciousness, and we provide an illustrative review of three main factors that shape prioritization—stimulus strength, motivational relevance and mental accessibility. We further discuss when and how this framework (i) is compatible with previous theories, (ii) enables new understandings of established findings and models, and (iii) generates new predictions and understandings.

Keywords: consciousness; nonconscious processes; function of consciousness; selection for consciousness

> [H]ere's the fundamental fact…by the time you are consciously aware of something, your brain has already done it. How else can it be? (Gazzaniga 2009)

The view that Michael Gazzaniga, one of the pioneers of cognitive neuroscience, expresses above seems to verge on triviality. Indeed, how else can it be? Yet, this seemingly trivial truth failed to find its way into the dominant theories of consciousness. These theories assume that non-conscious processes are powerful and efficient parallel processes, especially vis-a-vis low-level perception. Yet, high-level, 'central', integrated cognition is often left to conscious processes (Ajzen 1991; Dehaene and Naccache 2001; Baars and Franklin 2003; Tononi and Koch 2003). Conscious processes are endowed in this literature with powers and abilities that allow them to perform functions that cannot be performed non-consciously. Deouell critically referred to these abilities as 'magic dust' (Deouell 2020); in Dennett's terminology they are skyhooks (Dennett 1996).

The minimalist approach that we develop here is a framework that allows one to appreciate how non-conscious processing and conscious contents shape human cognition, broadly defined. The approach is composed of three principles; First, cognitive processes are inherently non-conscious.[1] Second, non-conscious processes, and elements of our cognitive architecture, prioritize information for conscious experience. Conscious 'events' are composed of these conscious contents and the non-conscious processes in which they (as well as non-conscious contents) take part. The third principle of the minimalist approach (henceforth: MinA) is that the duration of conscious events is an important determinant of human behavior.

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[1] By 'cognitive processes' we refer to post-perceptual computations, operations and simulations, which are best described in Marr's (1982) algorithmic-representational level. Where it is best to draw the line between perception and cognition is a matter of ongoing debate, with recent data suggesting meaningful interactions between bottom-up and top-down processes (Gilbert and Li 2013; Firestone and Scholl 2015). Given that perceptual processes are consensually regarded as non-conscious in nature, the argument that we develop here does not depend on where exactly the line is drawn.

Highlights

- The minimalist approach has three basic tenets
- Cognitive processes are inherently non-conscious, yet contents can become conscious
- Conscious capacity is limited, and prioritization for conscious experiences is determined by the cognitive architecture, signal strength, accessibility and motivational relevance
- Conscious events extend over time and mere duration matters
- The somewhat coherent narrative of our 'stream of consciousness' is the result of the ways in which non-conscious processes prioritize information for consciousness and how the conscious information changes non-conscious processes and prioritization

The approach we put forward here is minimalist in that it makes no *a priori* assumptions regarding the functions of consciousness. It is also minimalist in that it does not endow consciousness with skyhooks and magical dust. In the first section, we start by succinctly presenting our view of the functional abilities of non-conscious processes (cf. Hassin 2013; Hassin and Sklar 2014). In the second section, we use microanalysis to study seemingly conscious processes, and to argue that cognitive processes are non-conscious in nature. In the third section we then provide an illustrative review of the literature on prioritization, proposing three data-based factors that affect prioritization for consciousness (i.e., the speed with which contents become conscious). In the forth section, we introduce the notion of conscious events, highlighting the importance of seriality, and discuss the role of duration and the interplay between non-conscious processes and conscious contents. In the fifth section we discuss possible objections to the new framework, especially in terms of Zombies and epiphenomenalism. Finally, in the sixth and last section we discuss some predictions and implications of MinA.

As all scientists of consciousness know, defining our concepts is a crucial step in doing our science. Our definitions appear in Appendix 1.

Non-conscious processes

One of the few nearly consensual themes in the cognitive sciences is the online, high-level scope (breadth) of human consciousness is very limited. We think one thought at a time. We experience one feeling at a time. One motivation at a time. These thoughts, feelings and visual scenes might be complex in themselves, but they tend to be experienced as a unit, and very few units can be consciously experienced at any given point in time. For the argument we develop here it does not really matter whether we can simultaneously experience only one unit or a few. What matters is that the number is small (Kahneman 2011; Treisman 2012; Cohen *et al.* 2016; Chater 2018; Wu and Wolfe 2018).

In contrast, the processing capacity of our non-conscious processes is much larger. From sensation and perception (in five senses), to semantic processing and early integration, low-level processes are generally assumed to be non-conscious. Motor processes are largely non-conscious, from those delicate movements that make some of us good tennis players, to those that make all of us amazing stair climbers. Simple meaning making

while reading is non-conscious (how did you just understand the word 'word'?). Chunking of visual input into meaningful objects is mostly achieved non-consciously. The list of computationally demanding processes that can occur simultaneously is very, very long (see reviews in Biederman 1995; Oliva 2005).

There is less of a consensus when one considers higher-level non-conscious processes. Traditional views suggest that many of them require consciousness, but in the last three decades this dogma has been challenged (Gardner 2003; Dijksterhuis *et al.* 2006; Soto *et al.* 2011, 2019; Bargh 2012; Sklar *et al.* 2012; Hassin 2013; Dehaene *et al.* 2014; Hassin and Sklar 2014; Bargh and Hassin 2021). In recent years, a number of findings of non-conscious processes were challenged on theoretical and methodological grounds (e.g. Payne *et al.* 2008; Stein *et al.* 2011; Klein *et al.* 2014; Newell and Shanks 2014; Hesselmann and Moors 2015; Moors *et al.* 2017; Biderman and Mudrik 2018). Some of these challenges were counter challenged (e.g. Brooks and Stein 2014; Goldstein and Hassin 2016; Melnikoff and Bargh 2018; Sklar *et al.* 2018; Sherman and Rivers 2021), and the discussion is still very lively at the time in which we write this paper.

While the literature tends to focus on disagreements, some of which were mentioned above, we would like to highlight the agreements. To our knowledge, no theory or view has ever suggested that we can consciously run three parallel thoughts, five different and unique conscious emotions, or four conscious mental simulations (to say nothing about 10 of each, combined). So, in a deep sense, we feel that there is wide agreement. Whether it is just one process or very few: There is a consensus that our ability for conscious processing is very limited.

Given the discrepancy between the capacities of non-conscious vs. conscious processes, and our usual cognitive busyness, one of the following options must be true: either cognitive and motivational processes can only occur rarely, or they can occur non-consciously. We developed arguments in favor of the latter option, suggesting that every fundamental, basic level function that we can consciously perform, we can also perform non-consciously. We called this view Yes It Can, or YIC for short (Hassin 2013). We later qualified this suggestion by specifying that the evidence currently supports YIC in adults (Hassin and Sklar 2014; but see Hesselmann and Moors 2015 for objections; Goldstein and Hassin 2016 for replies).

While this previous work concerned the scope and abilities of non-conscious processes, in the current paper we take a complimentary approach, by closely examining conscious processes.

Cognitive processes

What happens to mental contents as they become conscious? They may be integrated with other contents, or disintegrated into sub-components; operations may be applied to them, or transformations might be used to change them (Cooper 1975; Logan *et al.* 1984; Tononi 2004; Baddeley 2010). They may be broadcasted to other ongoing processes, leading to new conscious experiences such as thoughts and emotions, to the activation of mental procedures, or to changes in preferences and decisions (Fazio *et al.* 1982; Petty *et al.* 1997; Dehaene and Naccache 2001; Lau *et al.* 2006; Tononi and Koch 2008; Koch *et al.* 2016). This is, of course, a non-exhaustive list. The first tenet of the minimalist approach suggests that none of these operations is conscious, and, ipso facto, none of them is done by consciousness. This gives the first tenant of MinA:

(1) All cognitive processes are inherently non-conscious.떼

While this principle may sound surprising at first glance, it is important to note that it is not entirely new. Similar ideas (that are echoed in Gazzaniga's quote above) have been proposed throughout the history of psychology by leading psychological scientists (see, e.g. Miller 1962; Neisser 1967; Nisbett and Wilson 1977; Jackendoff and Psychological 1987; James 1890; Velmans 1991; Wegner 2002; Mandler 1975).

To examine this principle, we propose to use microanalysis. In practicing microanalysis, one zooms in on a (presumably) conscious process and then moves slowly forward in time. One can think of microanalysis as taking a slow-motion video through a cognitive microscope. Microscopes allow scientists to move from seeing materials and surfaces as they appear to the naked eye, to seeing their components and underlying structure. Microanalysis as it is applied here does the same thing for processes that, on the surface, seem to us to be conscious: instead of looking at them from a distance, using larger chunks of space and time (Trope and Liberman 2010), we look at them from up close and use smaller units of time (see Siegler 2009 for a review of a similar approach that was used to examine insights in math; see also Aru and Bachmann 2017; Bachmann 2012; Werner 1956 for a microgenetic approach that examines the formation of conscious contents. For further elaboration see Appendix 2).

In the following sections, we first use microanalysis to examine the role of consciousness in a hypothetical decision. We chose to focus on decisions because it is commonly assumed that consciousness has a crucial role in decision-making (Evans and Stanovich 2013; Rogers 2014). In the following example we apply microanalysis to arithmetic, a formal system of rules that is applied to abstract representations. These types of processes have also been traditionally assumed to rely on consciousness, despite findings indicating that parts of the (neural) processes leading to the final stage occur before conscious experience (Libet *et al.* 1983; Baumeister and Masicampo 2010; Morewedge and Kahneman 2010; Sklar *et al.* 2012; Rogers 2014; Shields 2014; Ozkara and Bagozzi 2021).

Our analytic approach is dialectic in nature: We raise a hypothesis, consider its implications, often reject it and then move to the next hypothesis. In both examples, the discussion is meant as an illustration that, naturally, does not capture everything we scientifically know about decisions (or mental arithmetic). Crucially, microanalysis can be applied at any level of granularity. To go beyond the illustrations provided here, the interested reader can use it to examine processes that she is interested in, while taking into account the best and most recent science to date.

One cautionary note before we continue. Introspection is notoriously bad at getting at the heart of cognitive processes (Nisbett and Wilson 1977; Wilson 2002). It is important to note, then, that microanalysis is not a way of exploring cognitive processes, but rather a way of examining 'conscious contents'. The assertion that the contents of our consciousness are given to us directly and easily has been an accepted axiom in the cognitive sciences from very early on (e.g. Descartes 1637; for a discussion of the transparency of consciousness see Harman 1990; Kind 2003; Siewert 2004). The longer-duration conscious contents of the sort we consider here should, therefore, be accessible for report; what one is unable to find using microanalysis is unlikely to be consciously experienced (at least with simple-to-define contents). We elaborate on the distinction between microanalysis and introspection in Appendix 2.

Conscious choice

Let us imagine one has to decide between a vacation in southern Italy vs. northern France. Aspects of the decision come to mind. Warm weather, the Mediterranean and Pizza, vs. coldish weather, the Atlantic, and moules-frites (in the early months of 2021, when we write this paper, all of this sounds like fantasy, but these decisions are likely comeback to our lives). How do these aspects come to mind? One well-known determinant is accessibility. The higher the accessibility of a concept, the more likely it is to become conscious (e.g. Jiang *et al.* 2007; Costello *et al.* 2009). Other factors include emotionality, relevance and contents of working memory (e.g. Reinecke *et al.* 2008; Balcetis *et al.* 2012; Gayet *et al.* 2013; Pan *et al.* 2014). Generally speaking, we become aware of our thoughts. They invade or 'pierce' consciousness (Kang *et al.* 2017).

To discuss these issues more generally, let us assume that a choice involves a set of conscious Arguments and Feelings, AF_{1-n}, about each of the main options. What is in this list? The idea that humans are rational decision-makers, with a long list of analytic pros and cons, has been abandoned a long time ago (see Kahneman 2011). So AF_{i-n} may include information, relevant and less so, hunches, emotions and feelings such as fluency (Bechara 2003; Schwarz 2004, 2012).

Next, let us zoom in, move our analytical machinery to slow-motion and use microanalysis. How did the set AF_{i-n} come to your conscious mind? How did we move from moment in time $t - \alpha$, in which AF_{i-n} were not conscious, to moment t in which they were?

One possibility, that can be immediately rejected, is that AF_{i-n} is a random set of representations in our memory that happens to become conscious when we think about the decision. This option does not fit what we know about how memory works, or how we experience our lives. After all, AFs are usually somehow related to the question at hand and not a random list of thoughts.

This leaves us with two options. One, upon beginning the decision-making process a number of (proto) AFs become non-consciously accessible, and they, or a subset of them, are prioritized for conscious experience. This assumes that the AFs were already represented in memory and that a non-conscious prioritization process occurred. The other option is that the AFs were not represented in memory, and hence our mind had to develop and construct them online. This option assumes that the work of developing AFs is done non-consciously.

This analysis then suggests that AF_{i-n} were either developed, or prioritized, before they became conscious. Importantly, then, 'the work of developing the arguments and feelings, and/or prioritizing a subset of them, is achieved non-consciously'.

So far, we have argued that aspects of decisions are not formed consciously. This still leaves consciousness with a potentially crucial role in decision-making: integrating arguments and feelings into a decision. For simplicity, let us assume that the set of conscious arguments and feelings, AF_{i-n}, can be translated into one metric, that we consciously compute a set of weighs, W_{i-n} and that we can consciously use these weights to make a choice. Consciousness in this scenario is left with the meaningful function of weighing and integrating various considerations into a choice.

But how do W_{i-n} come about? How are these weights computed? As was the case when we analyzed AFs, one can immediately reject the idea that the weights are random, as random weights will render our decisions random. Next, one can suggest that, for each AF_i, W_i is chosen from a set of more-or-less good enough values. Crucially, this implies that the work of comput-

ing these values, evaluating them, or choosing among values, is achieved non-consciously. The last option, that the value is computed in its entirety before becoming conscious, also leaves the work for non-conscious processes.

It is easy to see how this analysis can go on *ad infinitum*. We can go on here to consider how one develops a set of AFs that will help her to compute each W_i and then to consider the idea that one integrates these arguments into a decision about weights. But microanalysis can be applied recursively to these stages too.

At the end of the process, whether it takes one round of the steps described in this section, or a few rounds, microanalysis gets us to a point where contents become conscious as a result of non-conscious processes.

Arithmetic

One might argue that the results of micro-analyzing the choice above is limited and does not apply to more fundamental mental phenomena. That microanalysis is not applicable to formal, rule-based knowledge structures that are known to require conscious processes for their operation (Dijksterhuis 2004; Morewedge and Kahneman 2010; Masicampo and Baumeister 2013). Two of the most prominent scientists of the mind, Kahneman (2011) and Stanislas Dehaene (2014), use arithmetic as the quintessential example for cultural systems of this sort that require System 2/conscious processes. Both begin their discussions with a very similar example:

> Try to compute 12×13 in your head (or 17×24 in Kahneman's case).
> Don't just go on reading. Try.

How did you go about it? Most of us have a quick answer. Some (like Dehaene) multiply 12×12 and then add 12. Others do 10×13 and then add 2×13. Still others might prefer 10×12 and then add 3×12. The result is, invariably, 156.

Now apply microanalysis. There are several possible alternatives of approaching this computation and only one (or a very limited set) occurred to you. How? What happened between the point in time $t - \alpha$, in which no approach to the question was conscious, and the point of time t, in which at least one was conscious? By now our argument should be familiar. Microanalysis suggests that the work of limiting the possible strategies (or developing one strategy) was done non-consciously. We do not know how much cognitive processing went into it. For some of us this example might be so overlearned that very little processing was required, just retrieval. For others, some non-conscious strategizing might have been needed. But for everyone, the processes that ended up with one (or a few possible) conscious strategies were inherently non-conscious.

In the next step we can ask ourselves, if the processes of coming up with a computation scheme is non-conscious, maybe the computations themselves occur consciously? Let us zoom in, and slow motion. How did you do the computation? For most of us, the answer to 10×12 simply appears in consciousness (it was either automatically retrieved or non-consciously computed; see Jackson and Coney 2005; Ric and Muller 2012; Sklar *et al.* 2012). The same is true for 3×12. And how did you add 120 and 36? Again, it was either automatically and non-consciously retrieved or non-consciously computed. If this is not true for you, and you had to break down 10×12 further (e.g. $10 \times 10 + 2 \times 10$), then apply microanalysis once again.

So even in one of the most formal and cultural systems created by *Homo sapiens*, what we get at the end of analysis is a process that is composed of conscious awareness of mental contents, interleaved with non-conscious arithmetic processes.

Interim summary

Microanalysis reveals that when it comes to conscious vs. non-conscious processing, our intuition and introspection are deceptive (Nisbett and Wilson 1977; Wilson 2002). Processes that seem to be conscious through and through turn out, upon closer examination, to be composed of conscious mental contents, accompanied by, and interleaved with, non-conscious mental operations. When consciousness flows, when we are not stuck, these non-conscious intervals are easy to miss. While this may sound implausible, similar blind spots are abundant. To take just one example, although blinking shuts off all input to our visual system, we do not consciously experience darkness when we spontaneously blink (Golan *et al.* 2016). It is only in the light of intentional blinking that darkness is consciously experienced. Similarly, only in the light of microanalysis we learn about the blanks between conscious contents.[23]

Microanalysis makes the division of labor clear: While we are aware of contents, we are neither aware of the processes that create conscious experiences, nor of those that implement the work that follows conscious experiences (see Fig. 1a; Miller 1962; Neisser 1967; Nisbett and Wilson 1977; Wegner 2002; Chater 2018; Mandler 2019). What we know about the multiplicity of brain processes at any given point in time leads us to believe that the idea that conscious contents and non-conscious processes are neatly interleaved, as they seem to be in Fig. 1a, is probably wrong. The processes are better illustrated in Fig. 1b, where non-conscious processes continuously and simultaneously lead to conscious events so that the conscious stream appears seamless, or at least somewhat seamless. For clarity of presentation, we adhere here to the simpler version.

This conclusion, although consistent with much prior thought, seems to conflict with evidence that suggests that conscious processing is necessary for information to reach higher areas in the neural processing hierarchy and for the performance of various cognitive functions (Ajzen 1991; Baars 1997; Dehaene and Naccache 2001; Tononi 2004; Van Gaal *et al.* 2011, 2012; Kahneman 2013; Yuval-Greenberg and Heeger 2013). It is important to note two points here. First, the structure of discoveries that are used to back such claims almost invariably involves a significant finding in 'conscious' processes (e.g. participants successfully exert inhibition following a stop signal) and a null finding in non-conscious processes (e.g. they do not exert inhibition). As many have argued before us, such a dissociation is problematic because it is based on a null finding, and null findings are often easy to come by (Kim *et al.* 2020; Stein *et al.* 2020; Skora *et al.* 2021). Secondly, as we have argued elsewhere (Hassin and Milyavsky 2014), arguments for the necessity of consciousness for high-level cognitive processes seem to be more intuitive and hence easier to accept. This leads to a blinding asymmetry: While researchers arguing for non-conscious functions are asked to rule out all conscious processing (Holender

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[2] We thank the artist Zohar Lee Katz for this illustration.
[3] Whether there are in fact actual gaps in conscious experience, and what is their nature, is an empirical question that is left for future experiments. The idea of segmentation of conscious events seems likely, given findings of robust segmentation of events from continuous streams of both perception and action (Zacks and Tversky 2001; Kurby and Zacks 2008). It may well be the case, though, that given the multiplicity of thought, the gaps in one process are 'filled' with contents of another. Interesting ideas regarding these issues may be found in the microgenetic tradition (e.g. Aru and Bachmann 2018, see Appendix 2).
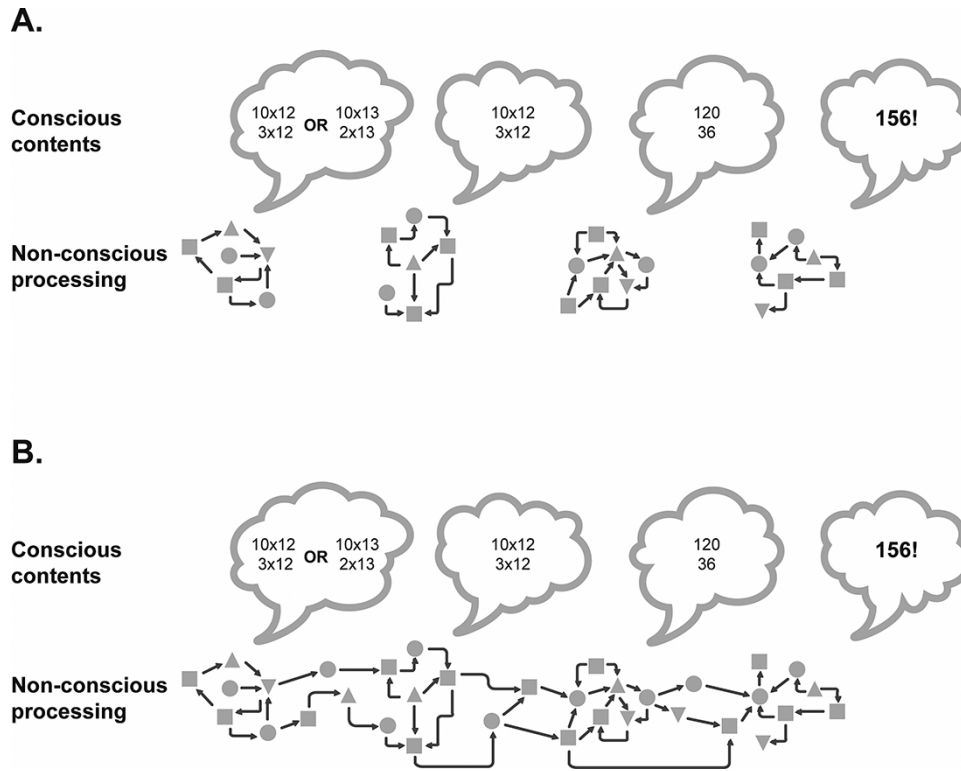
Figure 1. Illustration of a microanalysis of the process of computing 12 × 13 (see arithmetic Example on p.12). Conscious contents appear in the upper rows (cloud bubbles), in the lower row, non-conscious computations. Time progresses from left to right. Panel a illustrates a simplified account in which the non-conscious processes that lead to each conscious content are discrete. Panel b illustrates a more realistic model, where non-conscious processes operate continuously and simultaneously with conscious contents[2]

and Duscherer 2004; Newell and Shanks 2014), those who argue for conscious functions are not asked to rule out non-conscious processes, or even show evidence that processing was conscious. This bias leads to a systematic distortion in the literature (see also Bargh and Hassin 2021).

Arguably, some cognitive processes, whose operations are non-conscious, may 'require' conscious contents for their operations (Velmans 1991, 2009). This idea significantly deviates from the modal view of conscious processing and highlights a specific subset of the processes: those that cannot happen without contents becoming conscious. Determining which, if any, non-conscious cognitive processes strictly require conscious contents would call for new empirical tests specifically examined to this aim. This is an interesting empirical question for future research.

Prioritization

The second principle of MinA holds that one of the core functions of non-conscious processes (a function that, by definition, has to precede conscious experiences and hence has to occur non-consciously) is prioritization for consciousness. Prioritization may be implemented in three different ways. First, by a (set of) process(es) whose operation changes the likelihood that non-conscious contents become conscious (e.g. by simply boosting and inhibiting them). Second, prioritization may result from the architecture of cognition, e.g. from low-level systematic biases in the interplay between meaningful stimuli. These biases implement priorities, in the same way that the visual system prioritizes information from the fovea over information from the periphery. Third, prioritization may be implemented in a semantic landscape where the structure of the landscape, and attractors, more specifically,

play a causal role in changing the likelihood that contents become conscious. One may wonder why prioritization is important, given YIC, our view of non-conscious processes. The answer will be developed in the next section.

The literature on prioritization for consciousness has undergone exciting developments in recent decades, as the topic became more central to the cognitive and the neurosciences. While an exhaustive literature review is beyond the scope of the current paper, we survey below many illustrative findings. These findings support a simple model, with three major prioritization factors: 'stimulus strength, motivational relevance' and 'mental accessibility'. Stimulus strength is usually conceived of as a bottom-up factor and has to do with low-level visual features of the stimuli (e.g. differences in luminance and orientation; sudden onset). Stimulus strength can also be modulated by attention, which increases neuronal response in early sensory cortices (e.g. Hillyard *et al.* 1998; Eldar *et al.* 2013). This factor of prioritization has received much attention recently. Given the space limitations, we refer the interested reader to excellent previous reviews (e.g. Mack and Rock 1998; Itti and Koch 2000; Yantis 2005; Dehaene *et al.* 2006a; Koch and Tsuchiya 2007).

For each of the remaining factors we propose three somewhat distinct components.[4] To support our proposal, we survey findings from various paradigms of prioritization for consciousness. These include masking, rivalry, attentional blink, change detection, inattention blindness, continuous flash suppression

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[4]   The process of categorizing an experimental finding to a specific component is imperfect (e.g. prioritization of X may be affected by more than one component/factor). Yet, we believe that the advantages of this categorization outweigh its shortcomings.

(CFS) and repeated mask suppression. Each of these paradigms assesses prioritization differently, with its own unique features, so together they give us a broad and robust picture of prioritization.

Motivational relevance

Motivational relevance is the degree to which a stimulus is relevant to one's motivation. There are multiple ways in which relevance can come about. The stimulus can directly facilitate achieving a goal (e.g. food for a hungry person) or serve as an indirect cue (e.g. a restaurant sign). Motivational relevance may also be avoidant in nature (Higgins 1998, 2012b), signaling an object or situation that may threaten the pursuit of one's motivations (e.g. a spider for a spider-phobic). We identify three somewhat separate motivational relevance components: 'core motivation, goal relevance and emotionality'.

Core motivations

Core motivations include basic needs and drives like hunger and thirst and relatively permanent motivations such as the need to achieve, to belong and to be safe. Core motivations may increase and decrease in strength due to situational conditions and level of satiation, and they have been found to affect prioritization in various paradigms. For example, food deprivation (e.g. skipping one or more meals) leads participants to more quickly recognize masked and briefly presented food-related stimuli (Lazarus *et al.* 1953; Wispé and Drambarean 1953; Radel and Clément-Guillotin 2012). Similarly, in change blindness paradigms, people who have chronic sleep motivation—those who suffer from sleep disorders—detect changes made to sleep-related objects faster (Jones *et al.* 2005; Marchetti *et al.* 2006). Humans can develop new core motivations, as in the case of addiction. Indeed, patients with alcohol and heroin dependence detect changes to substance-related objects faster in a change blindness tasks (Jones *et al.* 2006; Bearre *et al.* 2007). Attentional blindness also captures prioritization: heavy drinkers, smokers, heroin users and gamblers detect words related to their addiction more than control words (Waters *et al.* 2007; Liu *et al.* 2008; Tibboel *et al.* 2010; Brevers *et al.* 2011). Safety concerns have similar effects: experiments in CFS (Abir *et al.* 2018) and in repeated mask suppression (Abir and Hassin 2020) provide evidence for a prioritization dimension of faces, such that threatening faces become conscious faster than less threatening ones.

Goals

'Goals' are desired end states that the person believes she knows how to approach, such as making it in time to the doctor, finishing a PhD or getting this Yes I Do from the love of your life. Like core motivations, it has been found that goals increase the likelihood and/or speed of becoming aware of relevant stimuli. Indeed, evidence shows that goal-relevant stimuli such as those for which participants are rewarded in a given task or those that help them complete the task are more dominant in binocular rivalry (Chopin and Mamassian 2010; Balcetis *et al.* 2012; Wilbertz *et al.* 2014), and become conscious more often during attentional blink (Livesey *et al.* 2009), even when attention is loaded by a concurrent task (Marx and Einhäuser 2015). In a more realistic setting, participants detect more changes in a change blindness task when the changes involve stimuli relevant to an ongoing driving task (e.g. potential collision hazards; Wallis and Bülthoff 2000; Koustanaï *et al.* 2012; Zhao *et al.* 2014).

Emotions

Emotions contain a component of action-readiness, leading to a tendency to act in a specific way toward a stimulus or situation that is motivational in nature (Wallon 1972; Frijda and Parrott 2011; Roseman 2013). Stimulus' emotional value—the degree to which it engenders emotion—can therefore serve as a cue to motivational relevance. Evidence shows that emotional words and expressions are prioritized for awareness. People consciously detect more conscious of masked negative words (e.g. Gaillard *et al.* 2006) or of negative words that appear in an attentional blink paradigm (Ogawa and Suzuki 2004; Kihara and Osaka 2008; Schwabe and Wolf 2010; Schwabe *et al.* 2011), and this effect is sensitive to lesions to the amygdala (Anderson and Phelps 2001). Similarly, negative expressions (e.g. 'baked babies') reach awareness faster in a CFS paradigm (Sklar *et al.* 2012).[5] In a related finding, people with spider phobias become aware of spiders more often during an attentional blink (Trippe *et al.* 2007; Reinecke *et al.* 2008) as well as showing stronger electrophysiological responses to spiders during attentional blinks (Trippe *et al.* 2007). Anxious participants become more aware of fearful faces during an attentional blink (Fox *et al.* 2005), see fearful faces faster in a CFS paradigm (Capitão *et al.* 2014) and are more likely to initially see a fearful face during binocular rivalry (Singer *et al.* 2012).

Accessibility

The third factor affecting prioritization is accessibility: the more accessible a mental event is, the more likely it is to become conscious. We define mental accessibility as the degree of ease with which a mental representation can be activated (Higgins 1996, 2012a). We identify three factors that contribute to mental accessibility: chronic accessibility, goal-related accessibility and transient accessibility.[6]

Chronic accessibility

Chronic accessibility may be caused by prevalence of stimuli in the environment or by a general (possibly innate) tendency to orient to a certain kind of stimulus or representation. The innate tendency shown by newborns for looking at upright face-like stimuli (Slater and Quinn 2001) e.g. is apparently maintained through adulthood. Accordingly, upright faces become conscious faster in CFS paradigms (as compared to inverted faces; Jiang *et al.* 2007) and are more consciously detected in inattentional blindness paradigms (Devue *et al.* 2009). Moreover, faces matching one's race are prioritized for consciousness in both CFS (Stein *et al.* 2014) and change detection paradigms (Humphreys *et al.* 2005; Hirose and Hancock 2007). In a related set of demonstrations, familiar religious symbols dominate more in binocular rivalry (Losciuto and Hartley 1963) and words in a familiar language become conscious faster under CFS (Jiang *et al.* 2007). Another canonical example of chronically accessible stimuli is one's own name, which is detected more during an attentional blink (Shapiro *et al.* 1997; Giesbrecht *et al.*

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[5] Note that emotional value comprises both valence and arousal (e.g. Lang *et al.* 2005). Although researchers often examine specifically negatively valenced emotional value, it is likely that arousal also contributes to the effect of emotion on prioritization. Indeed, both positive and negative arousing words are identified more during an attentional blink (Keil and Ihssen 2004; Anderson 2005) or when masked (Zeelenberg *et al.* 2006).

[6] We consider expectation to be a (strong) manipulation of accessibility. Indeed, when one is expecting a stimulus its representation may be so accessible that it is consciously experienced even when it does not in fact appear (Aru *et al.* 2018).

2009) and one's face, which reaches consciousness faster under CFS (Geng *et al.* 2012).

Accessibility from goal/motivational schema

As we argued above, objects/events that promote/hinder goal achievement may be prioritized for consciousness. Interestingly, accessibility is increased for representations of objects and events that are in the currently (or recently) active motivation/goal schema, even if the objects/events do not, in and of themselves, affect goal pursuit (e.g. if you are looking for a new baby stroller, baby toys might be prioritized for consciousness too). In other words, prioritization here is an incidental outcome of goal pursuit rather than an integral part of it. Indeed, evidence shows that stimuli that are visually or semantically similar to a target stimulus one memorizes become conscious more often during inattentional blindness (Most *et al.* 2005; Most 2013). Likewise, stimuli that match the contents of working memory are more dominant in binocular rivalry (Gayet *et al.* 2015) and reach consciousness faster under CFS (Gayet *et al.* 2013; Pan *et al.* 2014). In a striking demonstration, stimuli that were relevant to a goal in a previous task are more likely to be seen during an attentional blink (Raymond and O'Brien 2009) and tend to dominate longer in binocular rivalry (Chopin and Mamassian 2010).

Transient accessibility

Finally, 'transient accessibility' is caused by objects, events and thoughts that simply happen to cross our minds and thereby increase the accessibility of related mental events. This change in accessibility is the basis for priming phenomena where exposure (often incidental) to one concept facilitates processing related concepts (e.g. Neely 1977; Marcel 1983). Indeed, evidence shows that primed words and images are quicker to break suppression in CFS (Costello *et al.* 2009; Lupyan and Ward 2013; Stein *et al.* 2015), including when the priming stimulus is in a different sensory modality (Zhou *et al.* 2010; Tan and Yeh 2015; Ostarek and Huettig 2017). Similarly, semantically primed words are detected more often in masked priming (Pecher *et al.* 2002). The same phenomena are documented with expectations. When participants know the expected category of an upcoming stimulus, the stimulus reaches awareness faster under CFS and is detected more when backward masked (Pinto *et al.* 2015; Stein and Peelen 2015).

A note on surprise

The literature suggests that unexpected (and ex hypothesis, less accessible) signals bring with them an orienting reflex (Sokolov 1963) that may affect prioritization. Indeed, there are two findings in the literature that suggest that this may be the case. The first was reported by Mudrik et al. [(Mudrik *et al.* 2011); see Mudrik's failed replication in (Biderman and Mudrik 2018) and a successful related finding (Mudrik and Koch 2013)]. The other finding was reported by Sklar *et al.* (2012; but see Rabagliati, Robertson, & Carmel, 2018). Theoretically, we assume that while accessibility is often very important, other factors may interact with and sometimes override it. Thus, e.g. we (Abir *et al.* 2018) have shown that threatening faces break suppression faster than less threatening ones. A quick look at these faces suggests that the threatening faces are rarer in our students' environments and hence should be less accessible. Yet, it is easy to see why they would be prioritized: safety concerns may override accessibility. The question of the interaction of multiple determinants of prioritization is yet poorly understood.

Duration

So far, we argued that cognitive processes are non-conscious in nature and that non-conscious processes, as well as basic features of our cognitive architecture, prioritize information for conscious experience. This naturally raises the question of why prioritizing is important.

One of the hallmarks of conscious experiences is that they are severely limited in capacity, especially as it pertains to high-level cognitive processes (see Section I; but also Lamme 2003; Maier and Tsuchiya 2020). Given a narrow channel, the contents that become conscious tend to come one after the other. That is, they tend to be serial. Seriality of conscious experiences, in other words, is a by-product of the narrowness of our conscious experiences.

Narrowness and seriality are frequently thought of as limitations, especially when compared to the less limited and massively parallel non-conscious processes (e.g. Sperling 1960; Broadbent 2004). Their inherent advantage, however, is often overlooked (but see Kareev 1995, 2000; Fiedler and Kareev 2006). Owing to our biology, the way in which natural selection shaped us, action is largely serial. We (unlike some lizards) cannot move our eyes to two different locations at the same time and, obviously, we cannot walk in two different directions. We cannot pronounce two independent streams of thought, because we have only one output channel, nor can we write one thought while having another (but see Spelke *et al.* 1976). Verbal communication—one of the central pillars of human societies and coordinated action—tends to be serial, even when one talks to herself. This is simply how our biology works.

A narrow consciousness, with limited capacity, where events tend to be serial, seems to be a good fit to action and communication that are serial in nature. Narrowness and seriality might even be necessary, given that our mind needs to channel information from a massively parallel computational device—our brain—into a largely serially behaving organism (Bargh 1997).

Furthermore, a limited channel with seriality as a by-product, and memory at its disposal, allows for another type of (what might be a uniquely) human activity—narrative construction. The narratives that we live by vary. Some are very short and largely inconsequential and immediate ('it itches, so I scratch'). Others may be personal and cultural narratives that serve as our life-long guiding principles and as tools for building societies (Baumeister and Masicampo 2010; Bruner, 2004; Harari, 2014; Pennebaker and Seagal 1999; Wilson 2002). Given our biology narratives, too, must be communicated serially—first and foremost, to ourselves and then to others.

The third principle of the minimalist approach is inherent to serial events—'conscious events have a duration, and duration matters'. The duration that interests us here is duration of conscious 'events', periods in which one is predominantly consciously engaged with a certain stimulus, topic, issue or question. These can be times in which we admire the leaves in the fall; see passing cars when we cross the street; watch a bee approaching us; try to figure out a puzzle; and relive an event from the previous day, plan a vacation or simply think about consciousness. Defining an 'event' is both philosophically and psychologically challenging. We adopt Zacks and Tversky's (2001) definition: an event is 'a segment of time, at a given location, that is conceived by an observer to have a beginning and an end' (p. 3). Zacks and colleagues (Zacks *et al.* 2007) argue that events are hierarchically organized, which means that they vary considerably in terms of scope, amount of information and duration.

The duration of conscious events is important because while an event is conscious, 'non-conscious processes can attend to it within the (largely serial) narrative in which it is embedded'. Furthermore, contents that result from these non-conscious processes may get incorporated into this narrative, too. The longer the event, the more non-conscious work you can get, and the more integration with other bits of information, as well as the system's goals, motivation, needs and plans. And all of these fit into the one evolving event, one narrative, that currently occupies our conscious experiences.[7]

In discussing the functions of consciousness Dehaene (2014) writes 'One may even argue, with Daniel Dennett, that a main role of consciousness is to create lasting thoughts. Once a piece of information is conscious, it stays fresh in our mind for as long as we care to attend to it and remember it. The conscious brief must be kept stable enough to inform our decisions, even if they take a few minutes to form'. (p.100–101).

This quote highlights a general agreement regarding the importance of temporal thickness. It might be tempting at this point to adopt the view that Dehaene attributes to Dennett—that 'the (or a) function' ('role') of consciousness is to allocate time to mental events ('create lasting thoughts'). This is a temptation one should fiercely resist. To argue that time allocation is an active function of consciousness is to argue that, as a rule, we first become conscious of an event and then somehow consciously allocate time to it. Applying microanalysis to this claim, too, would quickly reveal that it is not the case. While it might seem to be intuitively true in some cases of higher-level cognition, in which we seem to be actively making a conscious decision to allocate time to a conscious event (e.g. when we decide to allocate time to a difficult decision), these allocation decisions should be subjected to microanalysis too. The analysis will teach us that these allocation decisions, too, are inherently non-conscious.

Conscious events tend to be temporally thick partly because the interaction between non-conscious processes and conscious contents is bidirectional. We have discussed prioritization for consciousness above (Section III). 'Crucially, conscious contents are followed by non-conscious processes that may alter the prioritization processes themselves' (e.g. they may create attractors that change the non-conscious prioritization of future conscious contents). To take a few examples, the vast literature on priming taught us that the simple thought TABLE is more likely to follow the simple thought CHAIR, than the simple thought Doctor (which in turn will tend to be followed by NURSE more than by CHAIR; e.g. Marcel 1983; Greenwald *et al.* 1996; Kouider and Dehaene 2007; Van Den Bussche *et al.* 2009). The simple positive thought SUN is more likely to be followed by a positive thought such as PUPPY than by a negative thought such as SNAKE (e.g. Fazio *et al.* 1986; Bargh *et al.* 1992; Cameron *et al.* 2012). Lastly, simple conscious thoughts—the contents held in our working memory—affect the speed with which subliminal contents are prioritized for consciousness (Gayet *et al.* 2013; Pan *et al.* 2014).

This, then, closes the circle: non-conscious processes form conscious contents that inhabit a rather narrow channel. Conscious contents are followed by non-conscious processes that act on or with these contents. Some of these processes modulate prioritization: conscious contents can be followed by changes in prioritization, increasing the likelihood that certain contents become conscious (and not others). This cycle allows humans to get from a single conscious experience (a micro-event) to a more or less serially developing, somewhat coherent, conscious event—the mental object that we usually refer to as a thought, a simulation, a narrative or an elaborate experience. Serial and evolving processing is, by and large, the product of non-conscious operations, the narrowness of conscious experiences and the tendency of conscious events to extend in time.[8]

Skyhooks, zombies and magic trampolines

In the first section we argued that MinA does not endow consciousness with skyhooks and magic dust (Dennett 1996; Deouell 2020), i.e. with abilities that are not anchored in simpler cognition. But at this point of the paper one might argue (along with one of the reviewers of an early version) that what we offer here amounts to no more than magical non-conscious trampolines and that 'it remains unclear why consciousness is even part of the system, because by [our] definition it cannot interact with non-conscious processing. Only non-conscious processing in some unclear way writes into and reads out of consciousness'.

This is a great comment, which we fear may occur to other readers of this paper, because it reflects a deeply rooted way of thinking about mental functions. Applied to consciousness, the idea is that in order for consciousness to have a role in our cognition it must 'do' something. If it does not do anything, it has no 'role' (function). And because, according to MinA, it cannot 'do' anything (cognitive processes are non-conscious) it has no function. It is simply epiphenomenal.

The logic is alluring, yet flawed. To see why, consider your computer's random access memory (RAM). Information is getting written to it and is being accessed from it—rapidly and randomly, as the name suggests. But, in itself, RAM does not actively do anything: it does not integrate information from different resources, it does not manipulate it, and it definitely does not send it to other parts of the computer.[9] Now, the fact that RAM does not actively process information does not mean it has no role in your computer. Without sufficient RAM your computer will turn into an intolerably slow machine (try downgrading your system to 1 Gb of RAM if you want to experience it). In the same way, the fact that consciousness does actively manipulate information does not mean it has no role in our mental lives [yet, we will not go as far as to suggest that you try to lose it if you want to (not) experience it].

We explicitly reject epiphenomenalism earlier in this paper. In fact, we devoted Section IV to describing the role consciousness plays in the cognitive system, channeling a massively parallel computational device—our brain—into a largely serially behaving organism. Conscious mental events are temporally thick and largely serial, and they allow for longer durations of (non-conscious) cognitive processing and to the creation of (largely) serial (partly) conscious narratives. Therefore, creatures without conscious events will be very different from creatures with conscious mental events.

The latter point brings us to another variant of this criticism. According to this argument, philosophical zombies—those creatures who are identical to us except for one small thing, having consciousness (Chalmers, 1999)—can accomplish whatever it is that we accomplish by having conscious contents. Hence, our model ends up as a disguise for epiphenomenalism. Dealing with the zombie argument is well beyond the scope of this paper, as the argument can be applied, *mutatis mutandis*, to every major

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[7] Note that data suggest that non-conscious processes can attend to non-conscious contents too (see, e.g. Jiang *et al.* 2006).

[8] We wholeheartedly thank Tory Higgins for suggesting this insight.
[9] Yes, its mechanics allow it to store information, but the same may be said about the mechanics of consciousness, that allow us to be aware of information.

theory of consciousness. We will make just two quick comments. One, there is an interesting debate about the validity and informativeness of the Zombie argument; we are uncertain about the theoretical implications of conceivability arguments in general. Secondly, like many before us (e.g. Dennett, 1991; Strawson 1999) we doubt whether zombies are really conceivable.

Working with the minimalist approach

In this section we discuss a number of conceptual, theoretical and empirical implications of MinA. We begin with the neuroscientific theories of consciousness. MinA is predominantly cognitive in nature. Yet, it is consistent with much of the prior neuroscientific data and views on consciousness and non-conscious processes. It allows us to derive essential components of these existing theories while highlighting limitations and ways of reconciling them.

Three prevalent theories regarding the neural mechanisms of consciousness will briefly be described and considered here: global neuronal workspace (Dehaene et al. 2006a; Mashour et al. 2020), local ignition theories (Zeki 2003; Malach 2007; Noy et al. 2015) and information integration theory (e.g. Tononi and Koch 2003; Tononi 2004). We will then examine their commonalities and differences, and elaborate on new contributions of MinA.[10]

Global workspace, local ignition and integration

Global Workspace Theory, first proposed by Baars (e.g. Baars 1997, 2002; Shanahan and Baars 2005; Seth 2009), proposes that the role of consciousness in cognition is to 'broadcast' conscious contents to a large set of specialist processors. This model inspired many subsequent theories, most notably the Global Neuronal Workspace (GNW), which is among the most prevailing theories of conscious processing.

In GNW Dehaene and Changeux (1998, 2011) begin by distinguishing two types of computational spaces in the brain. One is localized, quick, effortless and specialized in nature, and the other is a global workspace (cf: Fodor 1983). The global workspace allows interactions between perceptual systems, memory, attention and evaluation procedures. The information 'in' the global workspace can be further processed and integrated by these different systems.

Conscious (vs. non-conscious) perception in GNW is (among other things) 'needed in order to flexibly route a selected stimulus through a series of non-routine information processing stages' (Dehaene et al. 2014:79). These include recombining specialized cerebral processes in novel ways. 'Once we are conscious of an item, we can readily perform a large variety of operations on it, including evaluation, memorization, action guidance, and verbal report' (Dehaene et al. 1998, 14529).

GNW postulates that non-conscious and preconscious perception activate only a limited set of brain areas, mainly in occipitotemporal regions (Dehaene et al. 2006a). Processing in the GNW on the other hand is inherently conscious, and it involves many more areas of the brain, such as the dorsolateral prefrontal cortex, inferior parietal cortex, mid-temporal cortex and precuneus, which share information via long-distance connections (Dehaene et al. 2014; Mashour et al. 2020). These processes result in what the authors call global ignition—i.e. activation of many, related

and dispersed brain areas that remain active for relatively long periods of time.

GNW is often contrasted with more local models of conscious perception, the so-called 'local ignition' models (Zeki 2001, 2003; Malach 2007; Noy et al. 2015). Local models suggest that 'local ignition' in neuronal activity in the relatively early perceptual layers of the cortex is enough, in and of itself, to result in conscious perception. While at first sight GNW and local models seem starkly different from each other, conceptual and methodological ambiguities render them closer than they might seem (Noy et al. 2015).

Ignition, the process that accompanies conscious awareness of a percept, requires the formation of an integrated assembly of neurons, in which the pattern of activity is distributed to all members of the assembly. Malach and colleagues (Fisch et al. 2009; Malach 2012) highlight the importance of reaching a stable dynamics through reverberation and recurrence and argue that 'when such recurrent dynamics reaches a momentarily stable consensus – a [conscious] perceptual image is created in the mind of the observer' (Malach 2012, 8). Like their global counterparts, local ignitions are also characterized by activity which includes a self-sustaining component that results in increased duration (Malach 2012). Indeed, Fisch et al. (2009) highlighted the fact that brain activation significantly outlasts the presentation time of the physical stimulus.

A different approach to consciousness is manifested in Information Integration Theory (IIT; Tononi 2004, 2008; Tononi et al. 2016). IIT starts by identifying axioms regarding the nature of conscious experience and continues to propose a mathematical model of consciousness. The first axiom IIT posits is that conscious experiences contain relatively high degrees of information, i.e. that each experience is distinct from a great number of other possible experiences. For example, the experience of a white mug in the sink is distinct from that of a blue mug or a white plate or that of an empty sink. The second axiom is that experience is integrated. Thus, you cannot experience the color of the mug independently of its shape and position. Similarly, you cannot experience your right visual field independently of your left (barring a theoretical surgical intervention which leads to a fully split brain and therefore, ex hypothesis, two independent conscious streams).

IIT derives a measure of integrated information Φ (Phi), which estimates the amount of information produced by the system, above and beyond the information produced by its parts. Phi, argues IIT, is a numeric measure of the degree of consciousness in a system. In the brain, IIT tentatively links consciousness with parts of the corticothalamic system. However, because IIT identifies consciousness with an informational state, as opposed to a neural one, the specific areas involved in conscious experience at a given moment may change with the particular conscious contents present (Tononi et al. 2016).

IIT also posits that Φ depends on the spatial and temporal scale at which a system is described, and its value increases as one gets closer to the 'true' scale of information integration in the system (Tononi 2008; Tononi et al. 2016). In the brain, it has been posited that this optimal scale, the theoretical timescale at which consciousness operates, is between tens and hundreds of milliseconds (Tononi 2008), linking consciousness with at least somewhat extended duration.

This brief review of some of the prevalent neuroscientific theories of consciousness makes somewhat apparent the substantial areas of overlap between the different theories (for a thorougher consideration of this overlap, see Northoff and Lamme 2020);

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[10] Unfortunately, the scope of this paper prevents us from discussing other theories of consciousness (e.g. Aru et al. 2019; Bachmann 1997; R. Brown et al. 2019; Graziano and Kastner 2011; Northoff and Lamme 2020; Phillips et al. 2018; Zeki 2001, 2003; for a review see Northoff and Lamme 2020).

most relevant for the current argument is the consensus regarding the extended duration of conscious events (see also Aru and Bachmann 2017).

Duration of conscious events is also central to the minimalist approach, of course. However, MinA goes on to suggest that 'the mere duration of mental events matters': longer events bring with them more of the relevant non-conscious processes. Given that integrating information (e.g. with prior knowledge, motives and current context) is a prevalent process, longer conscious events are likely to also result in increased integration. Furthermore, the mere fact that conscious events extend in time means that more diverse processes may gain access to it. This is likely to result in increased accessibility of conscious contents to various non-conscious processes in the brain (e.g. those that produce behavior, emotions and decision-making).

Put differently, the minimalist approach reaches similar conclusions regarding the correlations between duration, integration and various downstream processing, but it highlights a different causal pathway. It places extended duration as the cause, rather than a mere correlate or outcome, of increased integration and diverse processing. Another crucial difference between MinA and other theories is that the MinA holds that conscious events are not 'necessarily' associated with information integration, nor are they 'necessarily' associated with global accessibility. Both are possible (maybe even probable) results of longer duration, but neither is necessary.

Prioritization

The minimalist approach put front and center a process that is currently less central to theories of consciousness—prioritization for consciousness. When theorizing about the contents that become conscious (vs. those who do not) current theories tend to limit their answer to considerations of signal strength and top-down attention (see e.g. Dehaene *et al.* 2006b). However, given the plurality of influences on prioritization for awareness reviewed above, prioritization processes are likely to be much richer and complex than previously thought. The current state of affairs also means that the neural substrates underlying prioritization may have been underestimated (but see recent examples otherwise, Aru *et al.* 2019; Weilnhammer *et al.* 2020). Understanding the neural substrates underlying prioritization for consciousness may therefore be an important step in adjudicating between different theoretical accounts of how consciousness is realized by the brain.

Dual processes

The intuition that slow speed, seriality, intentionality, effort, stoppability and consciousness tend to go hand in hand has characterized many dual process (and dual system) frameworks of reasoning and decision-making (for reviews see Dehaene 2014; Evans and Stanovich 2013; Sherman, Gawronski, & Trope, 2014). Often this intuition is a primitive of the theory. Posner and Snyder (1975) e.g. were among the first to propose such a view, and they wrote 'we propose three operational indicants of whether a process is "automatic" as we will use the term: the process occurs without intention, without giving rise to any conscious awareness, and without producing interference' (p. 56). To take another example, Morewedge and Kahneman (2010) note that 'We have identified system 1 with the automatic and mostly unconscious operations of associative memory….[system 1 often] automatically, quickly and effortlessly generates a skilled response to current challenges' (p. 439). Note that authors of these dual system theories often do not justify why certain features and not others tend to go hand in hand [General criticisms of dual-process processes were put

forward by Kahneman and Treisman (1984), Bargh (Bargh 1994; Melnikoff and Bargh 2018), and Keren and Schul (2009)].

It is important to note that MinA does not uniquely ascribe seriality, logic or any system-2 type characteristic to conscious events (neither does it ascribe uniquely associative process to non-conscious processes; Evans 2008; Evans and Stanovich 2013; Morewedge and Kahneman 2010; Neisser 1963; Sherman, Gawronski, & Trope, 2014; Smith and DeCoster 2000). Yet, as the discussion above makes clear, MinA suggests that consciousness, seriality and duration will tend to go hand in hand. Importantly, this does not mean that non-conscious processes cannot be long and serial (in fact, there are serial components in every neuronal process and in many hierarchies in the brain that seem to operate non-consciously). Neither does it mean that conscious events have to be long and sequential—they can definitely be short and all over the place. The minimalist approach merely suggests that consciousness, seriality and duration are often associated under naturalistic circumstances.

Put differently, many conscious events, at least in healthy adults, are likely to be somewhat serial. Yet, non-conscious events are less limited in terms of capacity, and a large number of them may happen in parallel. Everything else being equal, if a process benefits from seriality, it might be a better fit to conscious events in which seriality is dominant, than to non-conscious processes. When scientists, including us, make the cognitive system engage with serial non-conscious processes in the lab (e.g. Greenwald *et al.* 1996; Van Opstal *et al.* 2011; Ric and Muller 2012; Sklar *et al.* 2012), they should not be surprised if the effects tend to be weak.

A possible new categorization

The idea that all processes are inherently non-conscious paves the way for a novel, simple and informative categorization of mental processes. Specifically, MinA suggests that all processes are non-conscious and that contents may be conscious or non-conscious. In general, this allows us to focus on inputs and outputs as central determinants of mental functions and to suggest a 2 (input: conscious vs. not) × 2 (output: conscious vs. not) framework (for a related discussion see Aru *et al.* 2012). Thus, one can have non-conscious inputs and non-conscious outputs (e.g. spontaneous memory processes that lead to a change of behavior); non-conscious inputs with conscious outputs (e.g. insights after incubation); conscious inputs and non-conscious outputs (e.g. when semantic priming of 'chair' does not make one consciously think of 'table' yet facilitate RTs) and conscious inputs and conscious outputs (where doctors make us think of nurses).

New interpretations of old findings

One area in which the minimalist approach might be helpful is in thinking about neuropsychology vis-a-vis consciousness (Brown 2013, 2015). In what follows we illustrate this point by offering a tentative alternative interpretation to well-known cases in the history of psychology. Naturally, given the possible scope of these issues what we offer here is just a quick illustration.

Patients in vegetative states are the prima facie example for people who lack conscious awareness. The current view suggests, however, that there may be at least two types of patients: those with damage to non-conscious processes and those whose non-conscious processes are relatively preserved. Both may lack consciousness, but their underlying situation is entirely different.

In a famous series of papers Monti, Owen and their colleagues (Owen *et al.* 2006; Owen and Coleman 2008; Monti *et al.* 2010) used functional magnetic resonance imaging to examine the responsiveness of patients who were thought to be in a vegetative state.

While being scanned, patients were asked to imagine playing tennis or walking the streets of a familiar city. The brain activations of five patients suggested (via reverse inference) that they indeed followed instructions. One patient seemed to be able to use the technique to answer yes/no questions. The authors' interpretation suggests that at least two of these patients, who showed no signs of awareness in bedside examinations, were actually conscious and thus locked in.

MinA suggests that this inference may be unwarranted. It may well be the case that these patients have (partially or relatively) intact non-conscious processes, which they could use to follow simple instructions, but that either because of prioritization issues, because of duration issues, or because of awareness issues, they fail to become aware of the stimuli and action. In other words, the brain activation documented by this research may reflect non-conscious operations.

Another interesting case is patient N.N., described by Tulving (1985). N.N. has difficulties in episodic memory, which impact both his memory and his ability to imagine the future. Tulving describes the following conversation with the patient:

E.T.: 'Let's try the question again about the future.
What will you be doing tomorrow?'
(There is a 15-second pause.)
N.N.: Smiles faintly, then says, 'I don't know'.
E.T.: 'Do you remember the question?'
N.N.: 'About what I'll be doing tomorrow?'
E.T.: 'Yes. How would you describe your state of mind when you try to think about it?'
(A 5-second pause.)
N.N.: 'Blank, I guess'

Tulving interpreted the data as suggesting that N.N. suffers from deficits in autonoetic consciousness—conscious events that involve the self. MinA suggests another possibility: N.N. suffers from damage to the episodic mechanisms that brings about conscious events (Moscovitch 1995). That is, the deficit in his autonoetic consciousness is a product of the fact that non-conscious episodic events cannot become conscious (either because they are not retrieved or because they cannot be brought to consciousness).

Coda

Ulric Neisser, one of the founding parents of cognitive psychology once argued that 'our hypothesis thus leads us to the radical suggestion that the critical difference between the thinking of humans and of lower animals lies not in the existence of consciousness but in the capacity for complex processes outside it' (Neisser 1963, 10). We wholeheartedly agree with this sentiment, but we need to add one factor: the minimalist approach also suggests that the capacity to have longer-duration conscious events is crucial. To the extent that it varies between species, different stages of development and various mental states, this variance will have significant implications to the functioning of the animal in question.

Conflict of interest statement

None declared.

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Appendices
Appendix 1. Definitions and clarifications
Conscious: organism and event

Defining the adjective 'conscious' is notoriously difficult, yet there is a consensus that we should differentiate between at least two ways in which we use the term. We distinguish between (i) 'conscious' as a characteristic of an organism ('organism consciousness'; are birds conscious? amoebas? a vegetative patient? and a stone? see Rosenthal 2008; Edelman and Seth 2009) and (ii) 'conscious' as a characteristic of a mental event ('event consciousness'; whhere you aware of the extra h in the first word after the semicolon?; for similar distinctions see Dehaene and Changeux 2011; Shadlen and Kiani 2011; Boly *et al.* 2013; see also Hacker 2002). Note that these two meanings are not unrelated—having at least one conscious mental event (but preferably a stream of those) is a necessary condition for being a conscious organism.

The minimalist approach concerns how non-conscious processes and conscious events operate within a largely conscious animal—*Homo sapiens*. 'We therefore focus on event, rather than organism, consciousness'. This definition encompasses a large variety of cases, stretching from simple events such as mere perception (e.g. I am aware of the cup on the table), to much more complicated ones, such as being consciously engaged in a train of thought.

Consciousness: measuring

A mental event *X* is conscious if and only if it is phenomenologically experienced by an actor. For simplicity, we assume an actor whose cognitive system is intact; she is completely honest; fully motivated to cooperate and has intact reporting mechanisms. For such an actor, subjective reports can reflect the contents of her consciousness (i.e. the mental events she is conscious of). In other words, if an actor who meets these criteria denies seeing the Letter Y despite multiple questions from different angles, then it seems reasonable to conclude that she does not consciously see Y. If she consistently and repeatedly suggests that she sees a moving circle, then it seems reasonable to conclude that she consciously sees a moving circle (even if we know that she is in an apparent motion experiment in which there is no moving circle). This approach has had a very long tradition in neuropsychology (Battersby *et al.* 1956; Pöppel *et al.* 1973; Cowey and Stoerig 1991; Marshall and Robertson 2013). Subjective reports are also on the rise in cognitive and social psychology (Tononi and Koch 2003; Seth *et al.* 2008; Dienes and Seth 2010; Sandberg *et al.* 2010).

Note that conscious mental events should be 'reportable in principle', which does not mean that they are always reported. If a mental event is unreportable in any available way, and if every aspect of it is unreportable in any way, then it is not conscious (Rosenthal 2000; Cohen and Dennett 2011).[11]

This definition is straightforward in simple perception. Am I or am I not consciously perceiving, say, a triangle right now. Our definition suggests that in order to be conscious of the triangle, I must experience it as a triangle and that there must be a way for me to communicate the phenomenology at least to myself. The same logic holds for more complicated situations. Take motivational preferences for example. Assume you are comparing two motivations: your motivation to be a good father and your motivation to be a good scientist. If you consciously know which one of them you prefer, you should be able to say it. Or point. Or hint. Or blink. But if there is no way for you to know, no way that you can 'look inside' and 'see' which bar is higher, so to speak, then we would say that at this moment, you are not conscious of having a preference (see Kleiman and Hassin 2011 for a similar logic).[12]

Function

When one asks about the functions of consciousness one may have one of two meanings in mind. First, why did consciousness evolve and what function(s) did it serve that allowed it to be selected in evolution (if it were selected for in evolution). The second meaning has to do with what is it that consciousness does as part/characteristic of a cognitive system (see Seth 2009). The two questions, and their answers, are likely to bear family resemblance and shed light on each other. Our focus here is on the second question, hoping that it should provide us with good ideas for the first.

Process and contents

Throughout this paper we make a distinction between processes and contents. For the current purposes it is best understood at the cognitive level. Contents are composed of units of mental representations and relationships among them, whereas processes operate on and with these units, possibly incorporating other contents available to the mind. For example, the contents of the thought I LOVE MARY are I, love and Mary, and the meaning that is created by the words, their semantics and English grammar. The process of 'thinking' takes one from this thought, possibly incorporating more pieces of information and concerns, to the thought I SHOULD TELL HER. While on a neural level this distinction between content and process might be difficult to make, on a cognitive level, the distinction is simpler. For example, when considering what we know about cognitive schemas, one can easily differentiate between the contents of the schema (e.g. the doctor–nurse association) and the process related to it (learning the association and spreading of activation). Likewise, we can consider the processes of consolidation/retrieval as opposed to the content of a specific memory.

Appendix 2. Microanalyses, introspection and microgenesis

Given the turbulent history of introspection in the psychological sciences, it is important to stress that microanalysis is not a way of introspecting about how cognitive processes work (for the limitations of these introspections see, e.g. Nisbett and Wilson 1977). Rather, in microanalysis one reports whether 'contents' are conscious or not. The assertion that the contents of our consciousness are given to us directly and easily has been an accepted axiom in the cognitive sciences from very early on (Descartes 1637; Siewert 2004).

Consider the example we discussed in Section II. If narrowing down the set of possible strategies was a conscious process one would have had to consciously experience a larger set of strategies and then to consciously experience the elimination of some items from this list. This is indeed an experience that many of us often have. But in the examples above, the lack of conscious evidence for both sub-processes suggests that these contents were not conscious.

In this sense, microanalysis is very similar to subjective reports that are becoming increasingly popular in the cognitive and brain sciences (Tononi and Koch 2003; Seth *et al.* 2008; Dienes and Seth 2010; Sandberg *et al.* 2010). Interestingly, memory and forgetting, that are often cited as limiting factors when one discusses the value of subjective reports in threshold perception (e.g. Lamme 2006; Block 2007, 2011), are less of a concern here. Given a healthy brain, it is extremely unlikely that you consciously experienced a long list of alternatives, consciously worked on narrowing it down, only to have no conscious recollection of doing so seconds later.

Microanalysis also bears family resemblance to the microgenetic approach (Bachmann 2000; Brown 2013, 2015; Aru and Bachmann 2017). Broadly, the microgenetic approach suggests to closely examine the microtemporal formation and origins (genesis) of cognitive processes (Brown 2015). When applied to the formation of conscious experiences, this means examining how the transition from preconscious to conscious content temporally develops in micro-time. Findings from such an examination suggest that contents do not emerge instantaneously, in an all-or-none fashion. Rather, they arise in a gradual, time-consuming process, in which qualities are added as time progresses (Bachmann 2000, 2012; Aru and Bachmann 2017). There are two differences in emphases that are important to mention here; first, our main focus here was on experiences that are somewhat clear in nature, e.g. whether you experience the Number 9

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[11] Unfortunately, the field's attempts to create more 'objective' measures of conscious contents, that uniquely and exclusively measure conscious contents, have not yet succeeded (Cheesman and Merikle 1986; Reingold and Merikle 1988; Merikle and Reingold 1992).

[12] Sometimes, you are not conscious of having a preference because you do not have one. Other times, you do have a preference, but you are not conscious of it.

or not. Even if the process is gradual, one can apply microanalysis here to find a point of transition between no experience of 9 and an experience of 9—a transition that cannot be explained by consciousness. Secondly, while microgenesis focuses on how a single conscious content evolves over time, microanalysis also highlights a chain of several conscious contents.