Attentional enhancement and the contents of consciousness
(7902w)

Abstract

How are attention and consciousness related? Can we learn what the contents of someone's consciousness are if we know the targets of their attention? What can we learn about the contents of consciousness, if we know the targets of attention? Although introspection might suggest that our consciousness always follows our attention, a wealth of findings in cognitive psychology and cognitive neuroscience compellingly suggests that attention and consciousness are in fact two separate and independent processes. This paper purports to show that, in spite of these findings, the study of attentional distributions remains an essential component of the study of the contents of consciousness. For this purpose, I introduce a framework for systematizing the relations between attention in its different forms and consciousness in its different forms. Although philosophers and cognitive scientists have repeatedly highlighted the importance of such systematization, most details are still to be worked out. Here I take an initial stab at this project, based on the notion of degrees of informational enhancement.

1 The explanatory project

What is the relation between attention and consciousness? Can we learn what the contents of someone's consciousness are if we know the targets of their attention? What can we learn about the contents of consciousness if we know the targets of attention? The project of answering these questions is what I call the explanatory project: the project of using attention to furthering our understanding of consciousness.[1]

To be sure, this paper focuses on *phenomenal* consciousness, the kind of consciousness constituted by a subjective experience in which the world appears to us in a certain way, and which is usually characterized by its what-it-is-like qualities (Block 1995; Nagel 1974). In turn, and in line with a common practice in empirical research, I take attention to be a process involving the selection of a subset of the available sensory information for preferential processing (Posner 1980; Desimone and Duncan 1995; Carrasco 2011).

[1] Projects in this spirit have been explicitly endorsed, prominently, by Jesse Prinz (2012) and Michael Graziano (2013, 2019).

A wealth of recent findings in cognitive psychology and cognitive neuroscience cast doubt on the explanatory project, by evincing that attention and consciousness are probably two separate and independent processes. For this research suggests that attention does not really stand in a privileged relation to consciousness, and thus that studying attention might not be more relevant for understanding consciousness than studying other mental processes.

In this paper I argue that, in spite of these findings, the study of attentional distributions remains a fundamental component of the study of the contents of consciousness. In a nutshell, I will argue that the picture of attention and consciousness currently provided by the empirical sciences does still support the existence of tight and essential connections between their underlying processes. I propose that if attention is understood as an informational enhancer (a characterization strongly suggested by the way attention is conceptualized and operationalized in the empirical literature), it is possible to systematically map different forms of attention into different forms of consciousness by looking at the degree to which the relevant information is enhanced.

The plan for the paper is as follows. In §2, I briefly review some prominent empirical findings supporting a dissociation between attention and consciousness, and I introduce the general lines of my proposal for how to pursue the explanatory project on the face of this evidence, namely, the enhancement framework. In §3, I elaborate on the central notions and claims of the framework, and explain how it can be the basis for systematizing the relations between attention and consciousness. Sections §4-6 are devoted to defending the framework from some initial empirical objections, which arise from some of the findings presented in §2. I conclude in §7 with some final remarks about the limits of the explanatory project.

2 A three-front dissociation and how to overcome it

Current grounds for a dissociation between consciousness and attention span three main fronts: behavioral, neuroscientific and evolutionary. In what follows I present a somewhat more detailed yet quick survey of some relevant research. I sort the findings into four categories, depending on the kind of dissociation they support: attention without consciousness, consciousness without attention, opposing functions and effects of the two of them, and a double dissociation. Although this survey admittedly fails to be comprehensive, it can still lend us a good sense of the current empirical grounds for considering attention and consciousness as independent processes.

2.1 Attention without consciousness

Behavioral studies using masked priming show that subjects can attend to a feature of a stimulus (for instance, color) without having seen either the stimulus or the feature (one good example is Kentridge et al. 2008). Furthermore, a combination of this technique with a paradigm for testing object-based attention (Egly et al. 1994) has been used to show that subjects can attend to objects that they cannot see (Norman et al. 2013, 2015).[2] Moreover, even "high-level" properties such as being male or female can capture attention despite being invisible (Jiang et al. 2006).

Furthermore, patients with blindsight, who have impaired visual experiences due to damage in their primary visual cortex, are still able to effectively use visual attentional cues to detect targets in their blind field (Kentridge, Heywood & Weiskrantz 1999). Also, studies probing the tilt-aftereffect for visible and invisible adaptors show that both can be modulated by either spatial (Bahrami et al. 2008) or feature-based attention (Kanai et al. 2006), with stronger effects for attended adaptors. Additionally, fMRI reveals increased attention-related processing in the parts of the visual cortex encoding unseen stimuli on dual-task (Bahrami et al. 2007) and binocular suppression paradigms (Watanabe et al. 2011). Finally, priming effects on event related potentials can be enhanced by attention even when the prime is not consciously seen (Kiefer & Brendel 2006).

[2] Notably, the cues used to direct attention in these studies were fully visible. However, it has been shown that attention can be manipulated with invisible cues as well. See Fuchs, Theeuwes & Ansorge (2013); Kim & Blake (2005).

Hence, attention can operate on unseen targets. This tells us that knowing that someone is attending to something still leaves it open whether they have a conscious experience of that thing. Thus, for the explanatory project to work, we need to address the question: *when* is attention accompanied by consciousness? Is there a systematic way to pin this down? Are there common features that group together all instances of unconscious attention, on the one hand, and all instances of conscious attention, on the other? My proposal in §3 takes a stab at answering these questions.

2.2 Consciousness without attention

On the behavioral front, studies of iconic memory with the partial report paradigm suggest that it is possible to experience many more elements from a visual scene that those picked by selective attention (Sperling 1960; Landman et al. 2003; Block 2007). In addition, studies with a dual-task paradigm suggest that it is possible to have conscious experiences of elements in a visual scene outside the focus of attention, including natural scenes and animals (Li et al. 2002) and faces (Reddy et al. 2004, 2006). Finally, studies of visuospatial crowding suggest that it is possible to have conscious experiences of things one cannot attend to because the grain of attentional selection seems to be coarser than the grain of visual spatial resolution (Intriligator & Cavanagh 2001; Pelli 2008; Block 2013).

These behavioral results have been further supported by neuroscientific research. For instance, for the dual-task paradigm, fMRI reveals an increased response in the brain's fusiform face area, relative to baseline, for pictures of faces presented in the periphery (Reddy et al. 2007). This activity was independent of whether participants were fully attending to the faces or not, thus suggesting that perception of faces could occur with or without attention.[3]

[3] Note however, that there is conflict in the interpretations of the crucial finding in the dual-task paradigm, namely, that participants can use information from stimuli outside their focus of attention in order to complete a task. The studies described in this section treat these peripheral stimuli as consciously seen but unattended. However, as we saw in §2.1, these stimuli are sometimes treated as attended but unseen (Bahrami et al. 2007). My proposal is to treat these stimuli as both attended and consciously seen, albeit to lessened degrees than the stimuli in the central task.

It must be noted that the findings in this group face a critical methodological challenge: most of our current methods for testing consciousness do it by manipulating attention. The relevant paradigms typically rely on a task that requires a stimulus to be consciously perceived. However, participants will likely allocate at least some attention to any task-relevant stimulus (Cohen et al. 2012). Furthermore, *reporting* whether a stimulus was seen or not requires participants to attend to the stimulus. In other words, even if the stimulus was consciously seen *before* participants selected it for report, report-based methods cannot tap into this consciousness without thereby "contaminating" it with attention, so that what ends up being tested is no longer an unattended conscious content (Wu 2019). To overcome these challenges, behavioral researchers have proposed new methods such as no-report paradigms (Tsuchiya et al. 2015) and paradigms that test the visibility or invisibility of task irrelevant stimuli (Pitts et al. 2018).

Researchers also propose that the methodological disentanglement of attention and consciousness will probably require neuroscientific tools, for purely behavioral methods might not be enough (van Boxtel et al. 2010a). The proposal offered in §3 takes some first steps in this direction.

2.3 Opposite functions and effects

In addition to the studies suggesting that consciousness might neither require nor be required for attention, a dissociation between attention and consciousness seems to be supported on functional considerations. As a selective process, attention is often conceptualized as a mechanism for analyzing and filtering information (van Boxtel et al. 2010a). In contrast, it is not clear what the function of consciousness is or whether it even has a function (Block 1995; Haladjian & Montemayor 2015). Nonetheless, when functionally characterized at all, consciousness is regarded as an integrative and synthetic process (for instance see Tononi et al. 2016). Thus, consciousness and attention seem to be opposed in terms of general function.

Other research shows that even in cases when attention and consciousness do subserve the same task-specific function, they do so in different ways. For example, although manipulations of attention and consciousness both strengthen priming effects, attending to the prime does so by speeding up reaction times to congruent targets, while increasing the prime's visibility does so by slowing down reaction times to incongruent targets (van den Bussche et al. 2010).

More strikingly, some studies have suggested that attention and consciousness sometimes have opposing effects, so that attention sometimes seems to *impair* consciousness. Attention sometimes has been observed to diminish the intensity of perceptual experience (DeWeerd, Smith & Greenberg 2006). In a motion-induced blindness paradigm, where a salient stimulus is rendered invisible by a surrounding cluster of moving dots, purposefully attending to the stimulus makes it more likely to disappear from sight (Geng et al. 2007; Schölvinck & Rees, 2009). The effect is greater for more salient stimuli (Bonneh et al. 2001). Similarly, attention accelerates the Troxler fading effect: while holding fixation, some peripheral stimuli disappear faster when attention is directed to them (Lou 1999). Finally, distracting attention from the target stimuli in the attentional blink paradigm makes it easier to see the second target, which is missed when attention is fully engaged on the detection task (Olivers & Nieuwenhuis 2005).[4]

These findings tell against the idea that attentional processing is in the business of improving conscious perception: they suggest that sometimes one can only have a conscious experience of something if one is *not* attending to it. This opens up an cluster of interesting questions of relevance for the explanatory project, and especially for the proposal offered in §3, which is based on the idea that both attention and consciousness are correlated with informational enhancement. Thus, I will come back to discuss these studies after I have laid down the proposal.

[4] Relatedly, it was previously argued that attention and consciousness had opposite effects on afterimage duration and strength: attention appeared to decrease it, while consciousness (visibility of the afterimage-inducing stimulus) increased it (van Boxtel et al. 2010b; Koch & Tsuchiya 2007). However, recent evidence shows that attention and consciousness both increase afterimage duration (Travis et al. 2017).

2.4 Double dissociation and independence

Finally, a good body of neuroscience research supports a double dissociation between attention and consciousness; that is, that consciousness can occur without attention, *and* attention can occur without consciousness. Thus, the studies discussed in this section go beyond those discussed in §2.1 and §2.2, which only support a single dissociation.

For starters, attention and consciousness are associated with different underlying cortical activation patterns (for instance see Nani et al. 2019) and with different temporal structures (Fiebelkorn & Kastner 2020). The two of them also exhibit different MEG and EEG profiles. MEG revealed a correlation between stimulus visibility and mid-gamma activity in the occipital cortex. In contrast, attention correlated with high-gamma activity in the parietal cortex, (Wyart & Tallon-Baudry 2008). In turn, EEG reveals greater responses for consciously perceived than for non-perceived stimuli, regardless of whether the stimuli are attended or not (Forschack et al. 2017; Chica et al. 2010). Furthermore, the EEG components of attention have been observed for both visible and invisible cues (Travis, Dux & Mattingley 2019).

A double dissociation is also supported by considerations about the separate evolution of attention and consciousness (Haladjian & Montemayor 2015; Montemayor & Haladjian 2015). Montemayor and Haladjian argue that although there is some overlap between the two processes, there are many primitive forms of attention that do not require consciousness. These include spatial attention and feature-based attention, and the slightly higher-level object-based attention, all of which aid animals in navigation and detection of relevant environmental stimuli (Haladjian & Montemayor 2015).[5]

Summing up, there is reason to think that selective attention and phenomenal consciousness *must* come apart along many dimensions, despite partial overlap and occasional

[5] In their (2015) paper, the authors note that not all the animals that have these functions have *conscious awareness*. However, it is not clear whether this means that these animals lack *phenomenal* consciousness. The latter claim might be somewhat hasty, given the current methodological challenges for assessing the presence of this kind of consciousness. The former claim on the contrary seems plausible, if by *awareness* they mean something like reflective consciousness.

co-occurrence. This is a stronger claim than the one supported by the discussion on §2.3, which only states that attention and consciousness do come apart.

2.5 Overcoming the dissociation

It is now time to consider the implications for the explanatory project. As we saw, this project comprises three questions, namely: (1) What is the relation between attention and consciousness?, (2) Can we learn what the contents of someone's phenomenal consciousness are if we know the targets of their attention?, and finally (3) What can we learn about the contents of consciousness if we know the targets of attention? Our quick survey suggests that (1) attention and consciousness are neither identical, nor dependent on each other; in fact, each of them is a separate process that can occur without the other and can even hinder the other and (2) no, knowing which subset of information is selected and prioritized for further processing is not sufficient for knowing what the contents of someone's consciousness are. Attention sometimes is and sometimes is not accompanied by a conscious experience of the attended thing. Moreover, there may be no principled way of mapping the former onto the latter, and it might well be that the two of them are separable as a matter of necessity. Hence, studying attention may not be of particular value for learning when information of things in the world becomes the content of a conscious experience.

But what about (3)? Even if attention and consciousness are highly independent, can we not learn something about the contents of someone's conscious experience by knowing what things they are attending to?

In fact, there is reason to think that we can. Our current evidence allows that some forms of attention are necessary for consciousness, for instance, cross-modal attention, the kind of attention that integrates input from different sensory channels into a coherent representation of an object (Haladjian & Montemayor 2015; Montemayor & Haladjian 2015). Now, if at least some forms of attention are necessary for consciousness, and if there is a partial overlap between the two of them, then it is possible to use attention as a window into consciousness, provided that the conditions under which these two co-occur are carefully delimited

I propose that the current research on attention and consciousness suggests that (1) they are not identical but are bound to co-occur in some specific cases, (2) no, knowing which subset of information is selected and prioritized for further processing is not sufficient for knowing what the contents of consciousness are *because we also need to know whether the process of selection and prioritization is of the right kind*, and (3) knowing which information is selected and prioritized and what kind of selection and prioritization is being used does tell us which things constitute the contents of someone's conscious experience.

I will now introduce a framework that will help us defining the specific cases when attention and consciousness co-occur. My proposal can be summarized in four steps. First, it is a plausible consequence of the characterization of attention as a process of selection and prioritization (pervasive in the empirical literature)[6] that the selected information is enhanced within the relevant cognitive system. Second, information can be more or less enhanced: enhancement comes in degrees. Third, it might be possible to pin down a specific degree of enhancement such that, when information is enhanced to that degree, it becomes the content of a conscious experience. If we learn what that degree is, and if we can pin down the forms of attention that enhance information to that degree, then we can rely on attention as a window into consciousness. Finally, it might also be possible to pin down a specific degree of enhancement such that reaching that degree is necessary for information to enter the contents of conscious experience.

3 The enhancement framework

The proposal that degrees of attention could be the basis for systematizing the relations between attention and consciousness is not new. For example, cognitive psychologist Michael

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[6] For instance, see Cohen et al. (2012); Koch et al. (2016); Maier & Tsuchiya (2021); Nani et al. (2019); Nagavi & Nyberg (2005); Pitts et al. (2018).

Pitts and colleagues (2018) propose that different "amounts" of attention might give raise to different forms of attention, which might enable us to identify the forms of attention required for consciousness. On a similar spirit, philosopher Daniel Stoljar (2019) construes attention as a graded kind of processing and proposes that there is an amount of attention such that, when that amount of attention is allocated to a target, the target becomes consciously represented.[7] The present proposal intends to articulate these ideas with the aid of the notion of informational enhancement.

As I understand it, enhancement is a higher-order property that information has when some first-order properties are present, in virtue of which the organism can make better use of that information. Some of those first order properties include perceptual dimensions like precision or vividness. They also include computational properties, such as facilitation and suppression effects, implemented at the neuronal level. Indeed, suppression of responses to non-target or distractor information is sometimes necessary to optimize target information processing for the system's use.

One might think that enhancement is correlated with the amount of stimulus-related neuronal activity, so that more neuronal activity corresponds to a higher degree of enhancement. This picture is suggested by studies evincing increased neuronal activity for task-relevant as opposed to task-irrelevant stimuli (Desimone & Duncan 1995; Kastner & Ungerleider 2000; Corbetta & Shulman 2002; Reynolds & Chelazzi 2004; Raz & Buhle 2006; Treue 2003; Luck et al. 2000).[8] However, a problem with this view is that, in some cases, attending to a stimulus results in a decreased neuronal response. Feature-based attention is a good example (Reynolds & Heeger 2009; Thiele & Belgrove 2018). A neuron hardwired to "prefer" upward motion might fire below baseline when presented with a stimulus moving downwards and attention is directed to that stimulus (Martínez-Trujillo & Treue 2004).

[7] To be sure, Stoljar uses this framework to clarify *access* consciousness. In his view, increasing the degree of attention marks the transition between content being merely disposed for rational use, and its being *poised* for such use.

[8] For a defense of the view that the function of attention is signal amplification that can accommodate the present difficulties, see Fazekas & Nanay (2021).

Characterizing enhancement as a higher-order property, rather than identifying it with a first order property like neuronal spiking, enables us to bypass these difficulties. Firing below its baseline for its less preferred stimulus can be a way of conveying enhanced information of this stimulus' presence to neighboring neurons, thus biasing the competition more in favor of this stimulus.

Enhancement is essentially a comparative notion. For a piece of information to be enhanced, there must be a condition with respect to which the enhancement occurs. This condition might be the previous processing of the same piece of information or the processing of a different piece of information at the same time. It can also be both. For example, when you direct your attention to the pain in your leg, pain information is enhanced with respect to how that same information was processed a moment before, and with respect to how other pieces of information are being processed at the same time (say, it becomes more enhanced than the information of the article that you are reading).

I have also proposed that two thresholds of informational enhancement can be distinguished: one is the threshold that information must reach in order to be consciously experienced at all, while the other one is the threshold that, when reached, guarantees that information will be consciously represented. Call these $\mathbf{T^-}$ and $\mathbf{T^+}$, respectively. Given the characterization of enhancement as a comparative magnitude, $\mathbf{T^-}$ and $\mathbf{T^+}$ would be better characterized as relative, rather than absolute values. Whether they are reached on a single occasion for a piece of information may thus strongly depend on what other information the system is processing at the moment. This can also be influenced by stimulus strength and background conditions (such as context) or global states of the system (such as level of arousal).

It is, of course, an empirical question whether our neurocognitive systems implement something like $\mathbf{T^-}$ and $\mathbf{T^+}$, and how exactly these thresholds should be identified. That is, if enhancement is a measurable magnitude, determining which values or ranges of values of this magnitude correspond to $\mathbf{T^-}$ and $\mathbf{T^+}$ can only be determined empirically. Still, there is reason to think that this project is on the right track. There are at least two ways of starting to pin down these thresholds.

One way goes back to Pitts and colleagues' (2018) proposal. They hypothesize that there are different "checkpoints" in information processing, partially individuated by different amounts of attention. They show how this framework can be used to classify the wealth studies exploring the relations between attention and consciousness, on the basis of the kind of attentional strategy that each of them demands, in combination with the kind of stimulus used and its presentation conditions. Each study can be located in one of the following cells:

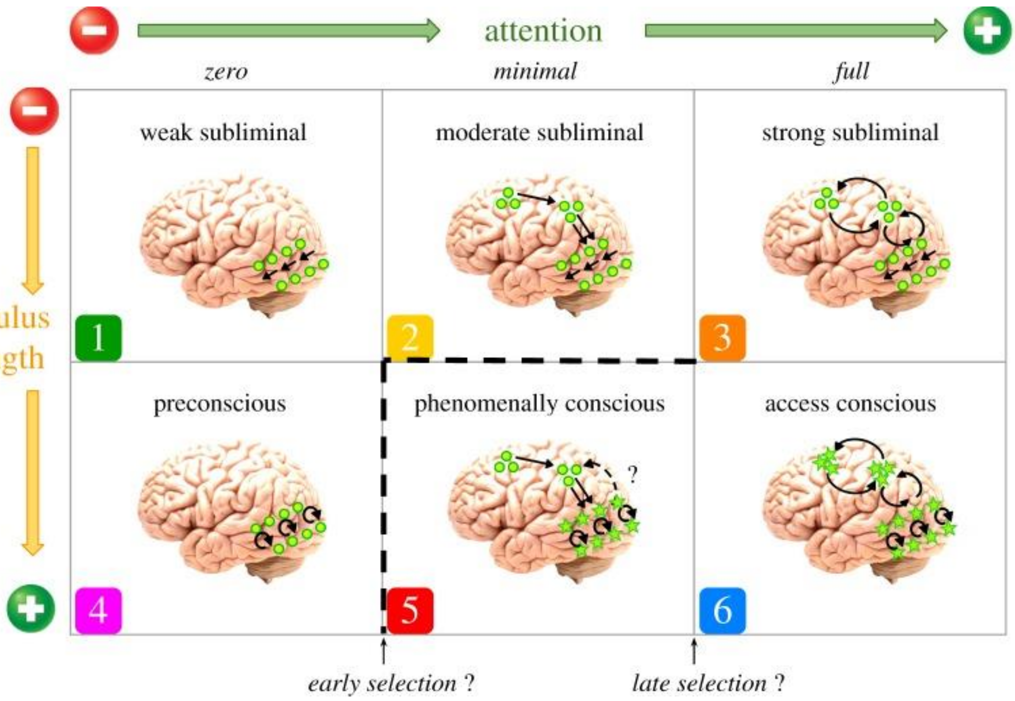

Fig. 1: An expanded taxonomy of the relations between attention and consciousness
Figure reproduced with permission from Michael Pitts. Republished with permission of The Royal Society (U.K.) from "The relationship between attention and consciousness: An expanded taxonomy and implications for 'no-report paradigms"; Pitts, M. A., Lutsyshyna, L. A., & Hillyard, S. A.; *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 373_(1755), Copyright 2018; permission conveyed through Copyright Clearance Center, Inc.

Pitts and colleagues' taxonomy provides a way to start pinning down **T-** and **T+** (at the border between cells 1 and 2, and between 5 and 6, respectively).

The proposal that there are degrees of enhancement that are either necessary or sufficient for phenomenal consciousness and which are given by relative thresholds is also congenial in spirit to a prominent theoretical approach to the study of consciousness, namely, Integrated Information theory (IIT). According to IIT, a system becomes conscious when it reaches the maximum level of integration of the information processed by its parts (Tononi et al. 2016; Oizumi et al. 2014). Very roughly, information is integrated when it has an irreducible causal profile. This occurs when the information carried by the whole system cannot be reduced to the sum of the information carried by the system's parts so that information carried by the whole generates causal effects that the sum of the information carried by the parts cannot generate. Information of the whole can also be causally affected in ways that need not be reflected in the information of the parts. A measure of the amount of informational integration in the system is symbolized as **Φ**. When **Φ** has a positive value, the system can be regarded as conscious. Moreover, higher values of **Φ** predict "more consciousness", or consciousness of more complex and sophisticated types.

Thus, a second way to pin down **T+** and **T-** could start by considering the relations of the notion of informational enhancement to the notion of informational integration. Some interesting interactions might arise. For starters, one might consider whether **T+** is the same measure as a positive **Φ** since both signal the point where conscious processing appears. If so, then degrees of enhancement could just be amounts of integration, such that for information to be more enhanced just is for it to be more integrated.

Note, however, that **T-** cannot be straightforwardly correlated with a degree of integration since IIT conceptualizes integration as *sufficient* for consciousness. In other words, once information is integrated, even if it the measure of integration is very low, the system counts as conscious, although its consciousness can be of a very basic kind. IIT thus predicts that there is no such a thing as integrated unconscious information.[9] In contrast, enhancement is not

[9] Against this prediction, Haladjian and Montemayor (2015) note that sometimes information is integrated outside of consciousness. On the other hand, it has also been argued that sometimes there is consciousness without integration (Brogaard et al. 2020). A supplementation of Integrated Information theory with the enhancement framework could provide a way to accommodate these cases.

like this: information can be enhanced below **T-**, and thus there is enhanced unconscious information.

One possible way to go would be to characterize **T-** as the minimum degree of enhancement that information must reach in order to become integrated. Enhancement and integration will then come apart in this respect: enhancement is a magnitude that is necessary but not sufficient for phenomenal consciousness, whereas integration is a magnitude that is both necessary and sufficient.

Alternatively, **T-** and **T+** might signal different amounts of **Φ**, such that information reaching **T-** gives rise to consciousness of more rudimentary forms (the ones corresponding to lower values of **Φ**), while information reaching **T+** gives rise to more sophisticated forms of consciousness (the ones corresponding to higher values of **Φ**).

Even if a further specification is still needed, the elements we have in hand already enable us to outline how the enhancement framework conceptualizes some of the cases of purported unconscious attention (from §2.1) and inattentive consciousness (from §2.2) in a way that supports the explanatory project.

On the one hand, failure to reach the higher threshold of enhancement **T+** could be the feature that identifies unconscious attention. Many of these cases involve factors that limit the amount of information that the organism can extract from the stimulus and the extent to which the system can make use of this information. Some of these factors are masks (Kentridge et al. 2008; Norman et al. 2013) or damage to cortical areas responsible for extracting specific kinds of stimulus information (Kentridge, Heywood & Weiskrantz 1999).

On the other hand, cases of purported inattentive consciousness can be tentatively characterized as cases where information of the relevant stimuli is enhanced at least up to **T-**, while leaving open whether **T+** is reached as well. Note that characterizing **T+** as sufficient for phenomenal consciousness does not entail that lesser degrees of enhancement are never conscious. However, one might distinguish between conscious information above and below **T+**, so that, for instance, the former is more elaborated, distinct or sophisticated than the latter. So if we characterize information of "unattended" stimuli in partial report, dual-task or crowding as enhanced above **T-** but not necessarily above **T+**, we might count these contents as conscious, albeit this consciousness is of a lesser degree than the one for attended stimuli.

At this early stage in its development, the enhancement framework already faces some pressing empirical challenges. Importantly, the framework seems to make the wrong predictions regarding some cases of perceptual attention; in particular, it seems at odds with the cases where attending to a stimulus seems to impair its conscious representation (introduced in §2.3). If attention is an informational enhancer, and if consciousness requires a certain degree of enhancement, then, why is it that in some cases attention makes stimuli disappear faster or even impairs perception?

4 Failed predictions I: Attended stimuli are more likely to vanish

The enhancement framework seems to make the wrong predictions for at least three cases: motion-induced blindness, Troxler fading, and the attentional blink. Since the first two effects have important commonalities, we will consider them together in this section. The conflicting predictions regarding the attentional blink will be discussed in the next section.

Motion-induced blindness and Troxler fading are perceptual effects that seem to occur due to hardwired information processing constraints. In both cases, a stimulus that remains physically present throughout disappears intermittently from perception. Motion-induced blindness occurs when a static stimulus becomes momentarily invisible due to the presence of a field of moving distractors (Bonneh et al. 2001; Schölvinck & Rees 2009). In turn, Troxler fading is the gradual disappearance of peripheral stimuli when the gaze remains rigidly fixated on an object for several seconds (Troxler 1804). The puzzling observation is that purposefully directing attention to these stimuli facilitates their disappearance. This is especially problematic for the claims that attending to a target enhances information of that target to a greater degree and that the higher the degree of enhancement, the most likely it is for a piece of information to enter the contents of a conscious experience. On the face of motion-induced blindness and

Troxler fading, it looks like one of these tenets has to go: either attention is not an informational enhancer, or else degrees of enhancement do not correlate with consciousness. However, once we consider the cases more closely, we will see that they need not be inconsistent with either claim.

In the motion-induced blindness study by Marieke Schölvinck and Geraint Rees (2009), participants were instructed to press a key when they noted that one of two yellow dots disappeared. The yellow dots were presented behind a grid of rotating blue crosses. See figure 2 for illustration:[10]

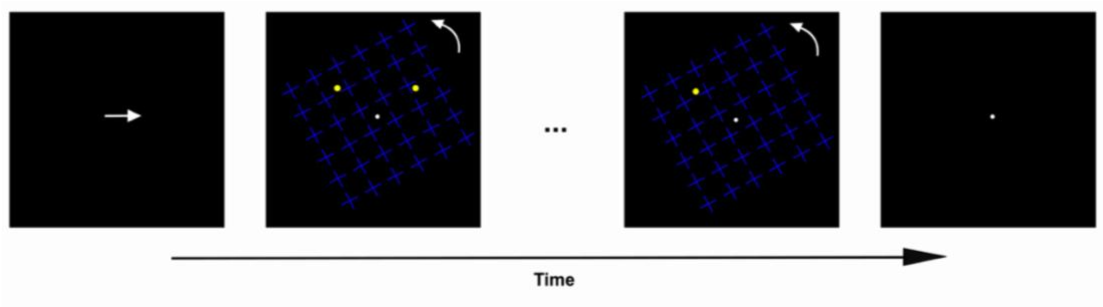

Fig. 2: Testing attentional modulations of motion-induced blindness
A standard trial in Schölvinck and Rees' study started with an arrow cueing attention to the left or the right. Then, two yellow dots and a grid of rotating blue crosses appeared. Participants must maintain fixation and press a key when they noted the disappearance of one of the dots. Figure presented here with permission from Marieke Schölvinck. Redrawn from *Journal of Vision* 9(1), 38, Schölvinck, M. L., and Rees, G., "Attentional influences on the dynamics of motion-induced blindness", 31-39, Copyright 2009, with permission from Association for Research in Vision and Ophthalmology.

Participants were prompted to focus their attention on either the right or the left dot while maintaining fixation on a center point. Once they noted that a dot disappeared, participants must press a further key indicating which of the two dots it was. The experimenters observed that attended dots were significantly more likely to be reported as disappearing.[11]

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[10] See an animated version of the stimulus at: https://commons.wikimedia.org/wiki/File:MotionBlindnessf.gif#/media/File:MotionBlindnessf.gif

[11] Interestingly, the second experiment in this study assessed the effect when attention was globally withdrawn from both the yellow dots and its rotating distractors by being engaged in a different task (detecting a stimulus in a rapid series presented at fixation). In this experiment, the motion-induced blindness display was presented in the upper-right quadrant of visual periphery. Three conditions were examined: no attentional load, low attentional load, and high attentional load; these were defined by the difficulty of the central task. This experiment showed that the greater the attentional load, and thus the lesser the amount of attention that could be used for the motion-induced blindness task, the longer the yellow dot remained invisible. This suggests that attentional processing indeed has a role in making stimuli pop into conscious experience. Still, these results may need to be contrasted with those of the

According to the enhancement framework, when attention is directed to the yellow dot, information of this dot is enhanced to a higher degree than information of the unattended dot. The account also predicts that other things being equal, the attended dot should be consciously represented if the unattended one is. Schölvinck and Rees's findings falsify this prediction.

But importantly, other things are not equal. Directing attention to one of the dots not only enhances information of the dot; it also enhances information of the contextual cues that trigger the dot's disappearance as a result of hardwired processing constraints. Furthermore, one cannot neatly disentangle object-based attention from spatial attention. When you attend to the dot, you also attend to the dot's location. At that location there is also information of the moving grid; this information is enhanced and computed for the generation of a conscious percept. Crucially, information of moving stimuli is prone to take over.

For one thing, it is beneficial for an organism to have information of the things that are moving around it, as this information might signal important changes in the environment correlated with, say, food or danger. In contrast, information of a stationary and unchanging stimulus is not as prone to keep drawing on the organisms processing resources once it has been registered. To sum up: attending to the yellow dot enhances also some contextual information, which is more potentially significant and thus enhanced to a higher degree, trumping competing information in reaching the comparative threshold for conscious perception **T+.**

This interpretation is in line with Schölvinck and Reese's account of their observations. They conceive motion-induced blindness as a completion process of the distracters into one homogeneous field, resulting in the target's being hidden from view. Completion implies neural competition between target and distracters. Directing attention within the motion-induced blindness display "favors" the distracters by enhancing distracter field completion, inducing target disappearance.

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attentional blink studies discussed below, which evince improved visibility under peripheral task conditions (see footnote 15 for further discussion).

Consider now Lianggang Lou's (1999) study of Troxler fading. Here, participants were instructed to attend to either the green or the orange disks in the periphery of a display while maintaining fixation on the center. See figure 3:

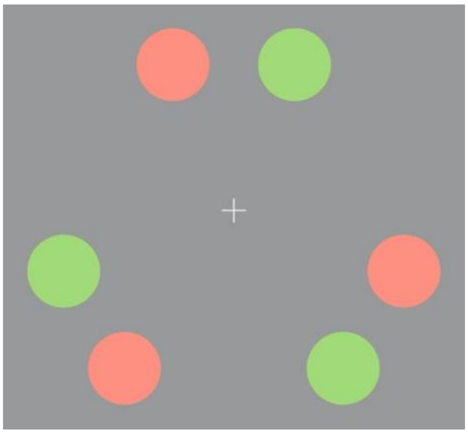

Fig. 3: Testing attentional modulations of Troxler fading
In Lou's study, participants must direct their attention to either the green or the orange disks while maintaining fixation on the center and press a key to report the disappearance of a disk. Adaptation (in color) from Lou, L., *Perception* 28(4), p. 521, copyright © 1999 by SAGE Publications. Reprinted by Permission of SAGE Publications.

Participants' task was to press a key when at least one disk disappeared and keep it pressed until the disk appeared again. They were then asked how many disks of each color had disappeared. Lou observed that the attended disks where more likely to disappear first.[12]

Like motion-induced blindness, this effect creates trouble for the enhancement framework because this framework dictates that attending to a disk enhances information of that disk and that this information is more likely to become consciously represented than competing information. But in Lou's study, the opposite happened: attended information was more likely to go unconscious.

An important difference between this study and the one by Schölvinck and Rees is the type of attention that each of them relies on. Schölvinck and Rees' study relies primarily on object-based attention: attention is directed on the basis of a stimulus with object-like properties. In contrast, Lou's study relies primarily on feature-based attention: attention is

[12] Interestingly, color was a relevant factor: green attended disks disappeared first about 95% of the time, while orange ones disappeared first only about 68% of the time.

directed on the basis of a property shared by several stimuli in the display, namely color. While object-based attention is usually constrained to enhance information from the specific location defined by the object's boundaries, feature-based attention is usually more evenly spatially distributed to bring out the relevant feature at any location where it is present.

That said, one crucial methodological aspect of Lou's study introduces an interesting interaction between feature-based and object-based attention. Participants in his study were encouraged to threat the three attended disks as forming a triangle, as this would facilitate the task of attending to all three of them simultaneously. If participants followed the instruction, their attention was not singling out any particular disk during this task. Instead, their attention picked out the object constituted by the three disks sharing the same color. Accordingly, the enhanced information was information of this object as a whole, *not information of any given single disk*. This already lessens the worries for the enhancement framework: since there was no trial where all three disks disappeared, there was no trial where the enhanced object faded entirely from consciousness.[13]

Still, a worrisome aspect of this study is that the unattended disks remained visible throughout. On the face of it, this contradicts the prediction that these disks should be less likely to make it into consciousness. However, here, too, considerations about contextual conditions and hardwired constraints are relevant. Information of the three-disk object is being enhanced in a specific context, which involves peripheral presentation and certain ranges of luminance and contrast. It is plausible that information of the stimulus is not enhanced independently of this contextual information. Contextual information is also enhanced and included in the computations that determine what the conscious percept will be.

In addition to these considerations, there is also an alternative way of characterizing informational enhancement, accommodating both Schölvinck and Rees's and Lou's findings. On this alternative characterization, a piece of information is enhanced when its capacity to drive

[13] On average, 1.2-1.4 disks disappeared per trial (depending on eccentricity).

neuronal responses is boosted.[14] Recall the case of feature-based attention making an "upward motion" neuron fire below its baseline when attention is directed to a stimulus moving downwards. We said that this pattern of firing conveys more information about the presence of a downward moving stimulus. One can also say that when attention is directed to the stimulus moving downwards, the capacity of this stimulus to drive the cell's response is boosted. The way the boost is expressed depends on how the cell typically responds to stimuli of this kind. For a neuron preferentially tuned for upward motion, information of downward motion presence is enhanced by suppression of firing. Analogously, enhancing information of the yellow dot in the motion-induced blindness paradigm or information of the three-disk triangle in the Troxler fading paradigm means potentiating the responses that these stimuli would typically elicit. Since these responses involve stimulus momentary disappearance, it is expected that this effect is more likely to occur.

These lines of explanation can also be extended to the remaining problem case, namely the attentional blink.

5 Failed predictions II: Unattended stimuli are more likely perceived

The attentional blink is the inability to identify the second of two targets presented in rapid succession. Figure 4 depicts a standard paradigm for testing this effect:

[14] For support for this view, see Reynolds & Heeger (2009); Fazekas & Nanay (2021).

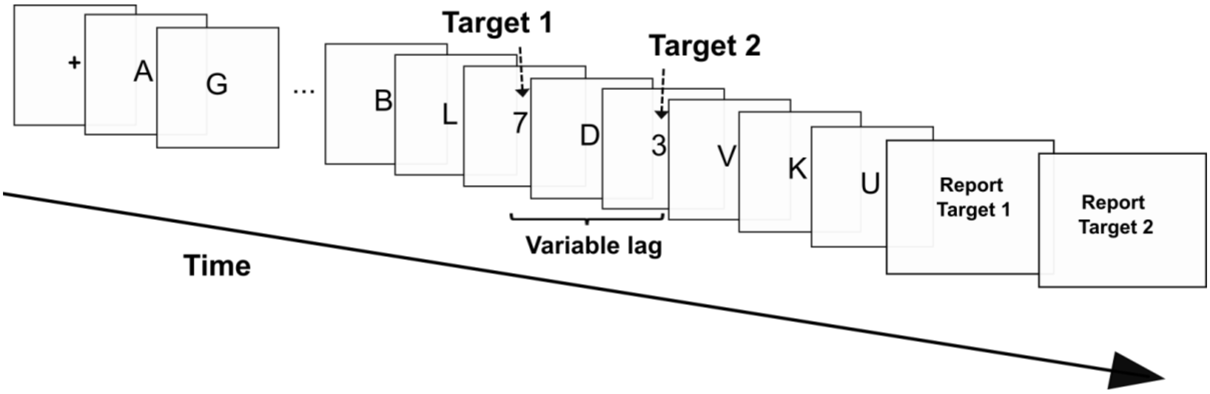

Figure 4: The attentional blink paradigm

Participants must report two targets appearing within a rapid succession of distractors, all presented at fixation. When the second target appears within 200-400ms after the first, participants fail to report it. This effect is known as the attentional blink.

The received explanation of the attentional blink is that the first target captures a great amount of attentional resources so that there is not a lot left for detecting the second. The effect is more pronounced when the lag between the two targets is shorter, which suggests that the "replenishment" of attentional resources after they have been used up in the first target takes some time. In fact, this effect is often taken to support the idea that attention is necessary for conscious perception: when attention is exhausted, the second target cannot be seen (Raymond et al. 1992; Chun & Potter 1995).

In the study by Christian Olivers and Sander Nieuwenhuis (2005), the targets were two numbers presented within a string of letters. Remarkably, the experimenters found that detection of the second target improves when attention is drawn away from the target-detection task. This finding seems at odds with the enhancement framework. The framework predicts that when less attention is available for a target, that target is less likely to make it into consciousness. However, this study suggests otherwise.

Once again, on a closer look, things need not be so. Note that the stimulus of interest is target 2. What is important is how much attention is available for enhancing *this specific piece of information* in every case. Fully engaging in the detection task enables the first target to use up all attention available, so that there is no attention or insufficient attention for processing the second target. Contrastingly, performing another, unrelated task at the same time hinders the first target's salience, thus allowing that the overall balance of attention reaches the second target as well. Hence, what we are looking at when comparing a standard attentional blink paradigm with an attentional blink as a concurrent task is not a case where allocating *less* attention to a *specific* stimulus (i.e., locally) makes that stimulus more likely to enter consciousness. Although less attention is allocated to the overall task where the stimulus is embedded (i.e., globally), this setting favors that attention is distributed in a way that *more* attention is allocated to the stimulus of interest.[15]

So far, I have explained how the three cases discussed can plausibly involve enhancement of information so that the result is a conscious percept of the relevant information. In doing so, I have mostly focused on the facilitation effects that underpin enhancement. However, it is very likely that the suppression effects of attention also play an important role in explaining these cases.[16] Attention can inhibit responses to information other than its targets. This can happen synchronically or diachronically. For example, it is possible that in the attentional blink the information of the second target is actively suppressed in order to better encode the information of the first target. If this were the case, then diverting attention away as Olivers and Nieuwenhuis did would result in a lessening of the active suppression effects, thus making the second target more likely to be consciously perceived. Similarly, it is possible that the attention-expedited Troxler fading and motion induced blindness are partially due to the interactions between information whose processing is directly facilitated and information that is actively suppressed.

[15] As suggested in footnote 11, it might be further illuminating to compare Olivers and Nieuwenhuis' results with those of Schölvinck and Rees' (2009) second experiment, where being embedded in a peripheral task diminished stimuli visibility. The account given in the main text could also explain this apparent conflict: in Schölvinck and Rees' experiment, making the relevant task peripheral plausibly diminished the amount of attention available for the stimulus of interest, compared to the amount available when the task is central. Notably, in this experiment, both tasks were in the same modality (visual), whereas in the Olivers and Nieuwenhuis study, they were not. While the detection task was visual, and was indeed presented at the center of the visual field, the concurrent tasks were either "mental" (engaging in free associations on task-irrelevant topics) or auditory (listening to music).

[16] This possibility was brought to my consideration separately by Slawa Loev and an anonymous reviewer from *Philosophy and the Mind Sciences*. I am thankful to both of them.

6 Attention and consciousness without enhancement?

A final challenge for the degrees of enhancement framework is posed by effortless attention (Bruya 2010; Montemayor & Haladjian 2015). In effortless attention, information seems to be processed without enhancement, at least in this sense: the distribution of attention seems flat, rather than having "peaks" for more attended stimuli.[17] If enhancement requires the peaks, that is, if it requires greater attention on some parts of the sensory input than others, then effortless attention would be attention without enhancement. Furthermore, if effortless attention is accompanied by phenomenal feelings (as it plausibly is), then there is phenomenal consciousness without enhancement.

One initial response to this challenge is that the enhancement framework is primarily intended to capture selective attention. Effortless attention, on the other hand, might not be of the selective type. However, the case remains of interest for the more overarching project of extending the enhancement framework to account for attention and its relations with phenomenal consciousness more generally, beyond just the selective types of attention.

7 Concluding remarks: Back to the explanatory project

I have argued that the enhancement framework is explanatorily useful, empirically well-motivated, and even consistent with evidence that initially seemed to contradict it directly. It also provides us with conceptual guidelines for approaching the daunting body of empirical literature from a systematic point of view.

This discussion has been motivated by three questions: (1) What is the relation between consciousness and attention?, (2) Can we know what the contents of consciousness are, if we know what are the targets of attention?, and (3) What can we know about the contents of consciousness if we know the targets of attention? I have proposed that (1) the relation between consciousness and attention is defined by informational enhancement: attention determines the degree of enhancement, and consciousness arises when a threshold is reached. I

[17] I borrow these suggestive terms from Sebastian Watzl (2017).

also proposed that (2) to know what the contents of consciousness are, we need to know what information is enhanced and the degree to which that information is enhanced. Question (3), in turn, remains largely open. In further pursuing our answer, we might need to concede that some aspects of the contents of conscious experience will remain unknown even if we know everything there is to know about how attention is distributed. For instance, we might remain ignorant about what it feels like when that information is enhanced. Still, attention might provide a helpful approximation to the scientific and objective investigation of the contents of phenomenal consciousness.

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