Degree project

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# Is There Support for Unattended Visual Phenomenal Consciousness? A Systematic Review

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## Abstract

The phenomenal experience of our visual perception, what it is like to be in that state, is something that we might take for granted. However, looking closer at the neural correlates of visual processing in relation to phenomenal experience we recognize that it is a complex issue. Whether our subjective experience of our visual representation of the world is attached to cognitive functions, like working memory and attention, or whether some sort of richness overflows such functions, is an ongoing debate within cognitive neuroscience. Advocates for overflow argue that phenomenal experience is the result of activity in posterior occipito-temporo-parietal areas and is independent of attention, while those within the non-overflow position mean that for phenomenal awareness to arise activity in higher-level areas like the prefrontal lobe is needed. Finding evidence for unattended visual phenomenal consciousness without access consciousness would support the overflow position since it could indicate phenomenal experience as independent of attention. In addition to this debate, researchers need to keep in mind what methods are being used to measure phenomenal experience, since several biases potentially follow studies using introspective measures. Through this systematic review, a search string provided empirical studies based on fMRI that investigated unconscious and conscious visual processing. The results of this review show little or weak evidence for unattended visual phenomenal consciousness and do not seem to overflow cognitive functions.


*Keywords*: cognitive neuroscience, fMRI, neural correlates, visual consciousness, overflow versus non-overflow

# Is There Support for Unattended Visual Phenomenal Consciousness?

## Consciousness

Consciousness is a troubling concept. The reason why, among other things, is that phenomenal consciousness (the phenomenal aspect of a state or what it is like to be in that state) and access consciousness (the ability to access sensory input and report about it) often fails to be distinguished as it is hard to imagine a conscious state without phenomenal consciousness, and without a separation of these concepts there is nothing but trouble ahead (Block, 1995). The importance of agreeing upon a common ground in consciousness research is emphasized by Revonsuo (2006), who contends that consciousness research as a whole lack a unified program, and he emphasizes the need to focus on the underlying biological mechanisms of conscious phenomena. To develop a comprehensive framework, further research and critical reviews of previous work are required, with an emphasis on identifying the neural correlates of consciousness. Thus, reaching a consensus on the definition of phenomenal consciousness and access consciousness could be a step toward a unified research program. Correspondingly, a definition was put forward by Block, where he suggests a separation of the two concepts, he states that: “Phenomenal consciousness is experience; the phenomenally conscious aspect of a state is what it is like to be in that state. The mark of access-consciousness, by contrast, is availability for use in reasoning and rationally guiding speech and action” (Block, 1995, p.1). This distinction has been further discussed within the debate of “overflow” versus “non-overflow” (Ward, 2018; Usher et al., 2018; Bronfman et al., 2018; Vandenbroucke et al., 2012; Naccache, 2018; Philips, 2016). Block's proposal of a separation between phenomenal consciousness and access consciousness served as a theoretical foundation for the overflow position, which posits that conscious experience transcends the limits of attentional focus and encompasses a richness of content that “overflows” cognitive functions (Usher et al., 2018; Bronfman et al., 2018; Vandenbroucke et al., 2012). Other researchers argue against this overflow and mean that access consciousness and its neural correlates is basically all there is to consciousness (Naccache, 2018) and even if there would be an “overflow” it lacks functionality since it seems useless in everyday life (Ward, 2018). Ward argues that phenomenology needs to be downgraded to its true level of functionless, she emphasizes her argument by applying it in an everyday context: “(…) a driver may hit a child who has run into the street because the driver’s attention was otherwise occupied and he failed to perceive the child. The alternative is that the driver saw the child in rich detail, but failed to compare his representation of the child to a previous version, or failed to encode the child properly into memory, and hit her with his car anyway. If this alternative is true, then phenomenology does not seem like one worth advocating for.” (Ward, 2018, p.5).

This review will adopt the earlier mentioned distinction of the two definitions of consciousness; phenomenal consciousness, and access consciousness, and consider phenomenal consciousness to include properties of visual perception. In order to define the term “unattended phenomenal visual consciousness”, we will assume that visual consciousness is based on phenomenal subjective experience, which aligns with the overflow position, and that visual attention is based on cognitive functions and relates to access consciousness (Lamme, 2004).

## Qualia and Phenomenology

Opening your eyes in the morning will result in a wide range of cognitive functions arising from physical processes in the brain and most of these functions will be accompanied by subjective conscious experiences. The scene of the sunrise hits the retina and the information is translated into neural activity that travels to a pair of small structures called lateral geniculate nuclei (LGN) where neurons respond to changes in brightness and color. The information continues its way to the primary visual cortex, known as V1 which is located in the back of the brain. Here, the neurons are sensitive to specific attributes from stimulus placed within the receptive fields, such as the direction of motion or the orientation of the contour. The information carries on to the extrastriate visual areas, focused on specific tasks; object recognition (inferior temporal cortex), shape formation (V4), face recognition (fusiform face area), and speed and direction of movement (V5) (Gazzaniga et al., 2019).

Explaining how these cognitive functions behind visual experience arise from their respective neural processes are the so-called “easy problems”. On the other hand, the “hard problem” is understanding why these cognitive functions are accompanied by conscious experience (Chalmers, 2007). Your subjective feeling of what it is like to experience the intense hue of a sunrise is hard to explain because the experience is based on a first-person perspective. These “raw” subjective experiences that cannot be described in words are referred to as qualia or the phenomenology of the experience. Although consciousness has been a hot topic recently, there is no consensus on why perception usually is accompanied by qualia, or why brain-based physical mechanisms would generate qualia at all. Further, the failure with providing a thorough physical explanation of how a material system like the brain gives rise to phenomenal properties corresponds to the existence of an explanatory gap in the web of modern-day materialism i.e., physicalism. Thus, as such the hard problem involves both an ontological as well as an epistemological aspect. Ontologically speaking: Why are there qualia at all associated with brain processes? (Chalmers, 2007) Epistemologically speaking: How do we explain the relationship between brain activity and subjective experience (Papineau, 2011)?

Cohen and Dennett (2011) argue that there is no such thing as a hard problem to begin with. They argue that consciousness cannot be separated from function and hence there is no "hard problem", rather it is a complex of "easy problems". Moreover, the phenomenal experience that arises from visual stimuli could perhaps be found somewhere along the visual information pathway in the brain, and the underlying mechanisms could be attached to or separated from the reportable attended consciousness (Zaretskaya, 2021). The next section will further venture into the debate about the potential separation of unattended phenomenal visual consciousness and access consciousness.

## Unattended Visual Phenomenal Consciousness

According to Lamme's (2004) "recurrent processing model", phenomenal awareness is described as a form of non-cognitive visual properties that are independent of attention and can exist on its own. Access awareness, on the other hand, is dependent on attention and the level of attention determines if this information becomes globally recurrent and reaches access awareness, where information becomes reportable. Further, Block (1995) argues that phenomenal consciousness and access consciousness could exist independently. Knowing which way is north without any external indications would be an example of access consciousness without phenomenal consciousness. On the contrary, imagine that you have intensively been writing on your thesis and suddenly you realize that the computer fan has started and been on for hours; the fact that you have been exposed to the sound from the fan, in the background of your conscious state, without attending to it would be an example of unattended phenomenal consciousness without access consciousness. When phenomenal consciousness is combined with access consciousness, and the experience is attended, it will result in "conscious awareness" and the content of the experience can potentially play a rational role (Block, 1995).

Over the last thirty years, visual consciousness has been intensively investigated (Nani et al., 2019). The possibility of conceptually distinguishing phenomenal consciousness from access consciousness has already been mentioned (Block, 1995) but more recent claims also state that, although visual awareness and visual attention are both associated with consciousness, they have different functions and neural correlates (Nani et al., 2019). Empirical evidence for access consciousness without phenomenal consciousness has been put forward by different studies, involving attentional cueing effects on sub-threshold or invisible stimuli and on patients with blindsight (Kentridge et al., 2004). Moreover, studies based on the pop-out effect, iconic memory, partial reportability, and dual-task paradigm provide evidence for a phenomenal consciousness without attention (Nani et al., 2019). On the contrary, Cohen and Dennett (2011) argue that no empirical study can neither confirm nor falsify theories that claim that there are separate neural correlates for phenomenal consciousness and access consciousness. The authors further argue that theories that

dissociate between phenomenal and access consciousness, like the "recurrent processing model", are biased and beyond the scope of science. These theories rely on subjective reports from a first-person perspective, which in turn is dependent on cognitive functions for their empirical testing. Therefore, Cohen and Dennett (2011) shine the light on theories of consciousness like the "neuronal workspace model" that specify which functions are needed for consciousness to arise. Further, they argued that a true scientific theory would include evidence of functions like attention, memory, and decision-making interacting to form a conscious experience. Alternatively, the possible biases following subjective self-reports and behavioral measures could potentially be avoided in a number of ways, for example by using physiological measures such as eye movements and pupil size (Tsuchiya et al., 2015). If experimenters can reliably manipulate subtle stimulus changes or give instructions, they could use these physiological measures to reliably judge a subject's perceptual content. The authors refer to this testing as a no-report paradigm.

## Measuring Methods

Block (2008) talked about the methodological difficulties in investigating whether unattended visual phenomenal consciousness and visual attention are separated. However, now the separation has been further explored with masking and change blindness tests while using functional magnetic resonance imaging (fMRI) (Nani et al., 2019; Zaretskaya, 2021). Neuroimaging made with fMRI has been used since 1990, both in clinical psychology, and presurgical planning, as well as in cognitive neuroscience. fMRI has been known to have a relatively high spatial resolution but a low temporal resolution (Glover, 2011). fMRI is based on magnetic resonance imaging (MRI) and uses nuclear magnetic resonance to produce images. Increased neural activity give rise to different detectable changes in the brain, two of which can be measured with fMRI. The first is termed the blood oxygenation level-dependent (BOLD) contrast. These images (obtained through the BOLD signal) depict the change in the magnetic field surrounding the red blood cells which are dependent on the level of oxygen of the haemoglobin. Since active neurons consume more oxygen than inactive neurons this change could be a sign of increased activity in certain areas (Glover, 2011). Another way to detect increased neural activity with fMRI is called cerebral blood flow (CBF), and it measures the increased local blood flow which could be an indication of the energy use by the brain. However, the use of fMRI has been discussed. Kosslyn (1999) argues that fMRI should not be used to determine a specific brain area for a specific psychological state, since it is a very complex issue to say that a psychological state, and that state alone, lead to a specific brain activity. Further, fMRI studies should be used to indicate correlation, but not causation. Still, Kosslyn (1999) states that fMRI could be used to develop a hypothesis within a theory and can thereafter be further tested.

Furthermore, there are optional measuring methods that can be used to investigate the potential separation between unattended visual phenomenal consciousness and visual attention, such as transcranial magnetic stimulation (TMS) and event-related potentials (ERPs) (Koivisto, 2012) or self-reports and behavioral measures (Rees et al., 2002). TMS uses a magnetic field to stimulate regions of the brain, and it has been used to probe the neural correlates of conscious experience (Silvanto & Pascual-Leone, 2008). ERP, on the other hand, uses the electrical activity of the brain as a measurement and has been used to identify neural activity associated with unattended visual stimuli (Vogel & Luck, 2000).

Regardless, fMRI could still be argued to be the best measuring method for the potential separation between unattended visual phenomenal consciousness and access consciousness since it is non-invasive and has a high spatial resolution. In contrast, other methods such as ERPs and TMS have limitations including lower spatial resolution compared to fMRI (Koivisto, 2012). While fMRI provides more objective-like measures of brain activity, self-reports and behavioral measures rely on subjective measures of brain activity. For example, a person might be asked to report on their subjective experience of a particular stimulus, or their behavior might be measured in response to a particular task. While these measures can provide valuable information about cognitive processes, they are more prone to biases than fMRI measures (Philips, 2016). To conclude, studies on the separation of the neural mechanisms between unattended visual phenomenal consciousness and visual attention using fMRI may contribute to more valid and reliable results than other methods and is hence the focus of this review.

## Aim

Conscious subjective experience is a fundamental part of experiencing life as a human being and has been an influential scientific topic in the last decades (Förster, et al., 2020; Skokowski, 2022; Lamme, 2004). However, understanding the neural architecture that gives rise to conscious experience is one of the most difficult questions to grasp in today's neuroscience (Förster, et al., 2020). This review focuses on the neural correlates of unattended visual phenomenal consciousness and investigates whether it is separated from visual attention, a question rooted in the debate about phenomenal overflow versus phenomenal non-overflow (Ward, 2018; Usher et al., 2018; Bronfman et al., 2018; Vandenbroucke et al., 2012; Naccache, 2018; Philips, 2016). The research on unattended visual phenomenal consciousness and its essential features has shown to be important for a better understanding of the visual system and for answering questions in other disciplines, such as philosophy and medicine (Zaretskaya, 2021). Moreover, further understanding our visual experience could lead us to better comprehend the phenomenal experience of individuals that are unable to communicate, for example, non-responsive patients, babies, and animals (Tsuchiya et al., 2015). Furthermore, in the pursuit of a consensus on the

definition of consciousness, re-evaluating previous research is a fundamental part and a potential contribution to the scientific process as a whole. This review explores articles based on fMRI studies from the last two decades to investigate the following question: Is there evidence for unattended visual phenomenal consciousness?

# Methods

## Search Strategy

Studies were selected through Medline EBSCO, Web of Science, and Scopus with the following search string; (consciousness OR awareness) AND (visual OR vision) AND (qualia OR phenomenology OR "neural correlates" OR phenomenal) AND (fmri OR “functional magnetic resonance imaging”).

With the selection criteria applied, the search string provided 109 results on Medline EBSCO, 123 on Web of Science, and 131 on SCOPUS on February 23, 2023. Duplicates were removed using Zotero and 189 results remained. After screening by the titles and abstract, based on the selection criteria, 17 results remained. Full texts were retrieved successfully from all 17 results, and 11 were excluded due to 5 different reasons: 1. The study did not use fMRI; 2. The studies focused on attended rather than unattended visual experience; 3. The studies were based on temporal measures rather than spatial ones; 4. The study focused on suppressed stimuli rather than phenomenal consciousness; 5. The studies focused on visual function rather than experience. Six results remained to be examined further (Fig. 1, PRISMA flow chart of the selection process).

## Inclusion and Exclusion Criteria

Seven selection criteria were chosen for this search. First, studies had to be based on fMRI experiments as this review aims to investigate the spatial neural correlates of unattended visual phenomenal consciousness. Second, the time constraint was set to published articles from the year 2000 onward. Third, studies should only include human participants. Fourth, exclusion should be made on experiments with focus on attention and working memory based on statements from Lamme (2004). Fifth, experiments where decision processing interferes too much between phenomenal experience and a report about it should be excluded. Sixth, only peer-reviewed articles should be included. Finally, all articles must be written in English.

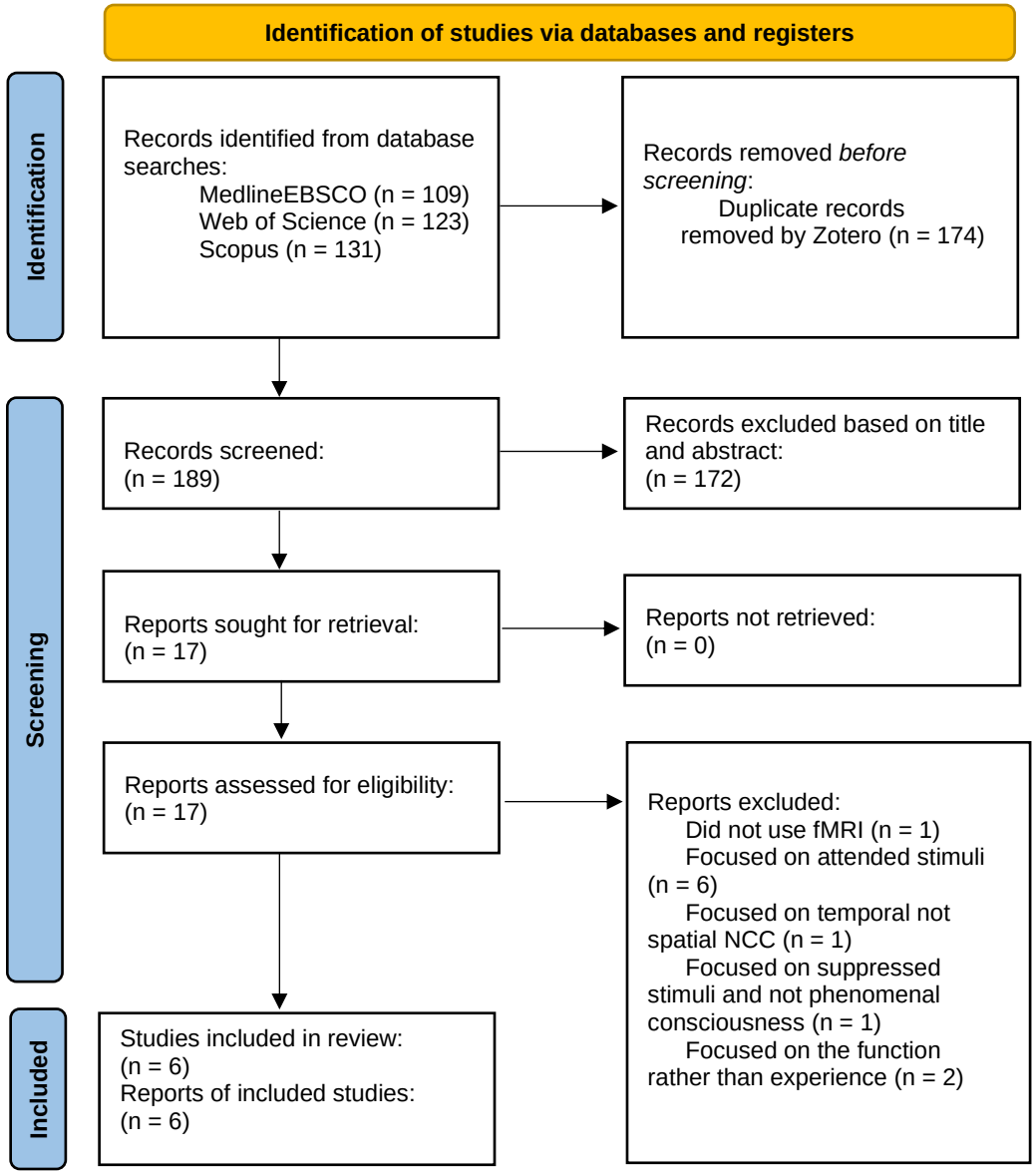
## Data Extraction

The data extracted from the results include information about the participants, the brain imaging methods, as well as the selected tests. Also, the data extracted from the results

were interpreted as to whether they lent more towards the overflow or non-overflow position. Further, the brain regions of interest were extracted.

**Figure 1**

*PRISMA Flow Chart of the Selection Process*




*From:* Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

# Results

Finding empirical evidence for unattended visual phenomenal consciousness requires investigation of studies probing conscious and unconscious visual processing. One useful method has been to compare consciously perceived visual stimuli against stimuli that are presented outside of awareness and thereby not consciously perceived by the observer. Scientists have been using subjective measures based on participant's reports and objective measures of participant's perceptual discrimination performance to investigate the question (Stein et al., 2021). In the articles presented below, the review presents empirical evidence that is based on both subjective and objective-like measures. As for the debate on overflow versus non-overflow, the first two articles presented below could be interpreted as evidence for overflow and the independence of unattended visual phenomenal consciousness, while the remaining four articles showed results in favor of the non-overflow position.

## Neural Correlates of Conscious and Unconscious Vision in Parietal Extinction (Rees et al., 2002)

This article investigated the neural correlates of conscious and unconscious vision in the patient GK, a 68-year-old male, who suffered a stroke to his right inferior parietal lobule, resulting in the neurological deficit visual extinction. Patients with left visual field extinction typically have no problem attending to one stimulus presented to either the left visual field (LVF) or to the right visual field (RVF). However, when presented with stimulus to both visual fields they have difficulties reporting the contralesional (left) stimuli, as it appears to be extinguished from their visual awareness. In the study, GK was tested using the double simultaneous stimulation (DSS) task during fMRI scanning. While being tested, GK was presented with stimuli in the form of a house or a face to either the LVF, RVF, or both and was asked to indicate whether he saw bilateral, unilateral left, or unilateral right stimulation. There were six different combinations presented randomly 60 times, resulting in 360 trials. The different combinations were then compared against each other, and the results showed neural activity in several brain areas even when GK was presented with stimuli that were extinguished from his visual field. This extinguished visual stimulus led to increased activity in the brain areas; ventral visual cortex, extrastriate cortex, some areas of the prefrontal cortex, and intact parietal cortex. Additionally, category-specific activation was observed in the damaged right ventral visual stream (right fusiform gyrus) for an extinguished face presented to his LVF. Overall, their findings showed that although GK was unaware of the stimuli presented to his LVF there was still activation in the ventral visual stream, confirming the possibility of unconscious visual processing in that area and hence, might indicate evidence of phenomenal overflow.

## Neural Correlates of Visual Extinction or Awareness in a Series of Patients with Right Temporoparietal Damage (Sarri et al., 2010)

In the study by Sarri et al. (2010) four male patients, aged 41, 67, 71 and 72 respectively, with right temporoparietal damage exhibiting visual extinction were studied to investigate awareness and extinction as well as their related neural correlates. They studied early visual cortex responses to extinguished stimuli, by retinotopic mapping of areas V1, V2, and V3. The patients were tested using double simultaneous stimulation (DSS) tasks where the patients were presented with visual flickering checkerboards either to the RVF, LFV, both, or none. This was done during fMRI scanning. Additionally, they monitored eye movements as this has been shown to impact the BOLD signal level in the early visual cortex. Their results showed significant activation ($p < .001$) of the retinotopic right visual cortex as a result of extinguished left stimuli which the patients were unaware of because of the right competing visual stimuli. From their evidence, it seems phenomenal experience is independent and overflows attention.

## The Human Visual System Differentially Represents Subjectively and Objectively Invisible Stimuli (Stein et al., 2020)

In the article by Stein et al. (2020), the researchers aimed to investigate how the human brain processes visually presented stimuli that are either subjectively or objectively invisible in order to further understand how the brain processes visual stimuli outside of awareness. In the study, functional magnetic resonance imaging (fMRI) was used to measure the brain activity of 43 participants (24 females and 19 males, mean age 22.7 years, SD 3.9, range 18 to 37 years) while they were presented with masked faces and houses that were either subjectively or objectively visible or invisible (subj-vis, subj-inv, obj-vis, obj-inv). The participants had to discriminate between the categories (house/face) while reporting whether the stimulus was visible or not. The participant's response determined the subjective visibility, while the experimenter controlled the objective stimulus visibility. Additionally, an experiment on behavioral masking efficiency was carried out to determine the ideal masking settings for achieving the objective invisibility of stimuli. Participants were presented with faces and houses on a computer screen and asked to discriminate between them. Various levels of masking were applied to the stimuli, ranging from low to high contrast. The order of the trials was randomized, and breaks were provided. The goal was to find the masking strength at which participants could not distinguish between the two types of stimuli effectively. The behavioral masking efficiency experiment involved 18 participants. However, one participant was excluded from the analysis due to a coding error, resulting in a final sample size of 17 participants (12 females and 5 males, mean age 21.8 years, SD 4.7, range 18 to 31 years). The brain regions of interest were; the visual cortex (V1) and lateral occipital

cortex (LOC), as well as category-selective regions; occipital face area (OFA), occipital place area (OPA), fusiform face area (FFA) and parahippocampal place area (PPA). The result for unaware visual processing in the subj-inv condition showed a significant correlation between discrimination of visual stimuli and category information in LOC ($p < .001$), OFA/OPA ($p = .028$), and FFA/PPA ($p = .001$), but not in V1 ($p = .88$). The results indicate that subjective awareness does not seem to overflow attention, rather that increasing category information from V1 to higher level processing is needed for subjective awareness.

## The Levels of Perceptual Processing and the Neural Correlates of Increasing Subjective Visibility (Binder et al., 2017)

The purpose of the study by Binder et al. (2017) was to test the levels-of-processing hypothesis, suggesting that the transition from unconscious to conscious perception is not an all or none shift but rather a progression that may be influenced by the level of stimulus processing, where low-level stimuli may produce a more gradual shift and high-level stimuli may result in a more distinct change. The researchers used visual backward masking, a brief visual stimulus (the target), followed by another visual stimulus (the mask) that interferes with the processing of the target, with a continuous flash suppression technique. The neural correlates were measured with event-related fMRI targeting several brain regions of interest (see Table 1). The participants ($n = 30$, 20 females and 10 males, mean age 21.94 years, $SD = 2.96$, all were healthy and had normal or corrected-to-normal vision) were exposed to two different tasks; (1) low-level where they reported the stimulus color, and (2) high-level where they reported the magnitude of the target digit. In addition, the Perceptual Awareness Scale (1. “no perceptual experience”, 2.“brief glimpse”, 3. “ almost clear experience”, and 4. “clear experience”) was used to measure the subjective visibility of stimuli during both tasks. The study showed complex results, many of which were not directly relevant to this review. However, looking at the bigger picture it seems attentional modulation in insulo-fronto-parital networks mediates the process of conscious perception without being directly involved in content representation but rather delegates the attentional resources for content representation to arise. However, the authors are careful in their conclusions when weighing different options for the analysis of the data.

## Attention but not Awareness Modulates the BOLD Signal in the Human V1 During Binocular Suppression (Watanabe et al., 2011)

The aim of the study by Watanabe et al. (2011) was to investigate if visual attention (attended) and visual awareness (unattended) are two dissociated functions. Binocular suppression, a phenomenon where the brain selectively suppresses the image from one eye in favor of the other, was used together with fMRI to measure the BOLD signal with a focus on V1. The participants ($n = 4$, unknown age and gender) viewed dichoptic images (Mondrian

and checkerboard, two different images presented to each eye) and reported their perceptual experience with a forced choice between “visible” or “invisible” while being under fMRI scans. The researchers used a two-by-two factorial design; visibility of target stimulus (invisible/visible) and directed attention (attention to target/nontarget location). The results suggest that the attentional state, rather than awareness, modulates the BOLD signal in V1. Regardless of visibility conditions, the authors found a highly significant effect ($p < .001$) of attention for all four participants. Additionally, experiments were conducted to measure eye positions, which ruled out the possibility that the results’ effects depended on involuntary eye movements. Furthermore, the results indicate that visual awareness seems not to extend to the lower levels in the visual hierarchy compared to the neural correlates of visual attention. These results agree with previous literature that the increase in the BOLD signal is associated with visual attention. However, the result challenges the previously established view that the BOLD signal in V1 also correlates with visual awareness and that phenomenal experience overflows attention. The authors suggest that previous studies may have failed to see this due to a lack of adequate control since attention and awareness are intimately interrelated.

## Activity in Early Visual Areas Predicts Interindividual Differences in Binocular Rivalry Dynamics (Yamashiro et al., 2014)

The study by Yamashiro et al. (2014) focused on a potential link between activity in early visual brain areas and binocular rivalry (BR) dynamics. To investigate the activity of unconscious processing the researchers collected fMRI measures from 12 participants (1 female, 11 males, age range 20–44-year-old, median 26) during periods of BR in which the visual stimulus was suppressed in a so-called Continuous Flash Suppression (CFS) experiment. In the CFS experiment, Mondrian patterns were rapidly flashed to the participant's dominant eye, while a probe stimulus was presented to the non-dominant eye. The purpose was to induce suppression of the probe by CFS. The probe stimulus was a rotating black and white checkerboard wedge with a smooth counterclockwise motion. This allowed researchers to assess onset responses without disrupting the CFS effect. Further, during the experiment, participants were instructed to provide continuous feedback on the visibility of the wedge, indicating whether it was completely invisible or partially visible, by pressing specific keys. The authors hypothesized that if visual areas play a role in BR dynamics, invisible stimulus activation should be weaker in participants with longer suppression duration and vice versa. The results showed increased activity in V1 for invisible stimulus compared to visible ($p < .001$) and an association between weaker response and longer suppression duration in V3 ($p = .006$) and V4 ($p = .029$). It appears that the function of the early visual regions in BR is not limited to representing the contents of the perception. Rather, they also play a role in shaping the perception. Further, in order to determine perceptual dynamics in BR both low-level as well as high-level areas should be involved.

**Table 1**

*Summary of included fMRI studies on visual awareness*

| Study | Number of participants | Brain imaging method | Test | Overflow or non-overflow | Brain regions supporting the results |
|---|---|---|---|---|---|
| Binder et al. (2017) | 30 | fMRI | Backward masking | Non-overflow | Insulo-fronto-parietal networks |
| Rees et al. (2002) | 1 | fMRI | Double simultaneous stimulation | Overflow | Ventral visual cortex, extrastriate cortex, areas of the prefrontal cortex, areas of the intact partial cortex, right ventral visual stream (right fusiform gyrus) |
| Sarri et al. (2010) | 4 | fMRI | Double simultaneous stimulation | Overflow | V1, V2, V3 |
| Stein et al. (2021) | 43 | fMRI | Continuous flash suppression | Non-overflow | V1, lateral occipital cortex, occipital face area, occipital place area, fusiform face area, and parahippocampal place area |
| Watanabe et al. (2011) | 4 | fMRI | Continuous flash suppression and | Non-overflow | V1 |
| Yamashiro et al. (2014) | 12 | fMRI | Continuous flash suppression and binocular rivalry | Non-overflow | V1, V2, V3, and V4 |

## Discussion

A consensus on the definition of consciousness cannot be defined without a definition of its parts (e.g., the distinction between phenomenal consciousness and access consciousness). This review aimed to contribute to the part of the definition concerning the neural correlates of unattended phenomenal visual consciousness with a focus on the debate on whether phenomenal consciousness overflows attention, or if attention is needed for phenomenal consciousness to arise, i.e., phenomenal non-overflow (Ward, 2018; Usher et al., 2018; Bronfman et al., 2018; Vandenbroucke et al., 2012; Naccache, 2018; Philips, 2016). As seen in this review, the results differ on whether visual phenomenal consciousness arises due to activity in the early visual areas alone or if higher-level processing like attention is needed. The studies investigating visual processing in patients with visual extinction (Rees et al., 2002; Sarri et al., 2010) clearly showed, that extinguished stimuli, which the patients did not report, still activated early visual areas. The researchers claim that the activation in these brain areas supports independent unattended unconscious visual processing in early visual areas without higher-level processing. This could indicate the assumption that phenomenal visual awareness can occur without attention, supporting those advocating for overflow (Usher et al., 2018; Bronfman et al., 2018; Vandenbroucke et al., 2012). Despite this indication, the challenge with the results discussed above (Rees et al., 2002; Sarri et al., 2010) is to say with certainty whether the stimulus is phenomenally experienced by the observer (Usher et al., 2018). Although their similar outcomes the main difference between the articles by Rees et al. (2002) and Sarri et al. (2010) was that Sarri et al. conducted a retinotopic mapping of the areas V1, V2, and V3 and monitored eye movements, which indicates higher validity compared to Rees et al. (2002). Despite that Rees et al. lacked these features, their results were enforced by the study by Sarri et al. (2010). In Rees et al. (2002), the result showed the most profound activation in the areas of the ventral visual cortex, extrastriate cortex, areas of the prefrontal cortex, areas of the intact partial cortex as well as the right ventral visual stream (right fusiform gyrus).

Moreover, support for the overflow position on visual perception in the literature can be found claiming that conscious perception can occur without the ability to verbally report what was perceived, in cases of forgetting or attentional amnesia (Usher et al., 2018). This limitation to report verbally is suggested to be a result of task relevance. In the case where the observer is told to focus their attention on a specific object the unattended stimuli become irrelevant, and the observer fails to report the stimuli. However, they may still have a phenomenal experience of the stimuli. A solution described by Ward (2018) suggests that memory failures can be ruled out by immediate reports in repeated inattentional blindness experiments and that such experiments have shown that inattentional blindness is in fact a perceptual deficit, supporting the non-overflow position. However, no-report paradigm

measures could potentially be used to eliminate these confounds altogether (Tsuchiya et al., 2015). Although, a limitation of the no-report paradigm is whether unconscious stimulus processing rather than subjective conscious experience is being measured. Further, this paradigm could potentially increase the objective evidence for the overflow versus non-overflow debate, whereas the authors (Tsuchiya et al., 2015) believe that this method would generate evidence for overflow. Unfortunately, the search for this review did not provide studies that used a no-report paradigm.

In favor of the non-overflow position, Watanabe et al. (2011) was the first study to show empirical evidence that attention, rather than awareness, modulate the activity in V1. Their results showed that there was a highly significant effect of attention regardless of visibility conditions, which indicates evidence against the overflow position. Agreeingly, in their comprehensive whole-brain analysis, Binder et al. (2017) proposed that attentional modulation plays a crucial role in mediating the process of conscious perception. They found that insulo-fronto-parietal networks are indirectly implicated in content representation, primarily by allocating attentional resources instead of being directly involved in content representation itself. In addition, Yamashiro et al. (2018) deepened this idea since their results showed that the function of the early visual regions in binocular rivalry, where increased activity in V1 is associated with higher visibility. However, both low-level and high-level areas should be involved in shaping perception as well as representing the contents of perception, which indicates that attention is needed for awareness to arise. This aligns with the result found by Stein et al. (2020) who further claim that increasing category information to higher level processing is needed for a phenomenal experience, i.e., activation from V1 to category-selective regions (OFA, OPA, FFA, PPA). Contrary, Bronfman et al. (2018) suggest that while focal attention may be necessary for binding elements, it is not necessary for conscious registration of visual elements. A study by Bronfman et al. (2014) using color discrimination showed that participants could discriminate between colors despite that their working memory and attention were directed to a different task. The researchers, therefore, claim that conscious experience overflows that of cognitive access.

Overall, the evidence regarding unattended visual phenomenal consciousness is ambiguous. Nevertheless, based on the data collected from fMRI studies in this review, a conclusion can be made that evidence against unattended visual phenomenal consciousness is slightly tipping over. There are however limitations to this review, and no bold conclusion should be pursued with these results. During this review, it has been clear that the debate regarding overflow versus non-overflow is complex and vivacious. With different researchers pointing in different directions, it seems the debate will go on, at least until further empirical evidence is provided.

## Limitations

An overall limitation of all the studies included in this review is the challenge that arises when measuring a subjective experience with objective-like measurements such as fMRI. On the other hand, Philips (2016) argues that the nature of experience is hard to find through introspection and that those advocating for overflow can always continue to insist that it exists due to the instinctive feeling of "what it is like" to be. Further, some of the resulting articles had few participants (Sarri et al., 2010; Rees et al., 2002; Watanabe et al., 2011). Due to the possibility of low statistical power hindering the detection of differences in small sample sizes, the results should be interpreted with caution. In Yamashiro et al. (2018) authors were included as participants, and this could lead to potential biases. Moreover, Watanabe et al. (2011) point out the difficulty in adequately separating attention and awareness which showed to be a limitation when retrieving articles from this review's original search. Naccache (2018) agrees that the distinction between phenomenal conscious and unconscious representations is vague and lacks a clear definition that cannot be firmly established. Furthermore, a deeper knowledge of the field could potentially have resulted in an improved search string and selection of studies.

## Social and Ethical Aspects

If there is an overflow in consciousness, it suggests that there may be aspects of our experiences that we are not fully aware of because we are not technically speaking paying attention to them. This could impact our understanding of our own thoughts, feelings, and behaviors. Regarding personal agency, if our unconscious processing would significantly influence our experiences, as proposed by those advocating for overflow (Usher et al., 2018; Bronfman et al., 2018; Vandenbroucke et al., 2012) it raises questions about how much control we have over our own actions and decisions. Additionally, it raises questions about the responsibility for our actions. Should we be held accountable for actions that are influenced by sensory input that we are not consciously aware of?

Considering the ideas above, establishing a unified approach may influence mental health, social justice, and education. Deepening our knowledge of how we experience the world may impact treatments and interventions within mental health. Furthermore, unconscious biases and stereotypes might impact our social interaction with one another. In education, there might be aspects of learning and memory that the traditional educational system does not contain and might benefit to take into consideration.

The development of research on the debate around overflow versus non-overflow could influence research within artificial intelligence (AI). If consciousness research could find the underlying mechanisms of phenomenology there might be a possibility to answer the question of whether machines can achieve true consciousness (Watanabe, 2022). These

findings could bring evidence and arguments to ethical questions around the development of more advanced AI systems.

## Conclusion

Consciousness might be a troubling concept. However, future research might one day come closer to the truth about the neural correlates of phenomenal consciousness and access consciousness and unify the two camps using more precise measures and evaluations as suggested by e.g., Tsuchiya et al. (2015). For now, according to the results of this review, fMRI activation together with self-reports and behavioral measures seem to support the non-overflow position. Hence, there appears to be little or weak support for unattended visual phenomenal consciousness.

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