# Is Visual Consciousness Discrete or Continuous? An Integrative Perspective Based on Attentional Blink

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## Abstract

Is visual consciousness discrete or continuous? The attentional blink paradigm from the perspective of attentional inhibition serves as an important tool for addressing this question. The attentional blink paradigm refers to the rapid serial presentation of multiple stimuli (approximately 10 per second) at fixed spatial locations, where participants are required to report one or more targets among several distractors. This paradigm can effectively attenuate conscious awareness to varying degrees by controlling lag time, thereby circumventing problems prone to confusion in participants' subjective judgments while also avoiding errors caused by exogenous attention. Arguing for the coexistence of both modes under attentional blink based on integration theory perspectives provides a compatible theoretical framework for different viewpoints on this issue, and facilitates further investigation into how factors such as measurement methods, stimulus materials, participant response modes, processing levels, and attentional load influence the mode of visual consciousness. Future research can optimize experimental methods and procedures based on the aforementioned factors, thereby enabling in-depth empirical investigations into this question from the attentional blink perspective.

## Full Text

### Is Visual Consciousness Discrete or Continuous? An Integrated Perspective Based on Attentional Blink

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**Abstract:** Is visual consciousness discrete or continuous? The attentional blink paradigm, which operates from the perspective of attentional inhibition, serves as a crucial tool for addressing this question. In this paradigm, stimuli are presented rapidly (approximately 10 per second) at a fixed spatial location, and participants must report one or more targets among several distractors. By controlling lag time, the paradigm can effectively weaken consciousness to varying degrees, thereby avoiding both confusion in subjective judgments and errors caused by exogenous attention. Based on an integrated theoretical perspective, this paper demonstrates the coexistence of both discrete and continuous patterns within attentional blink, providing a compatible theoretical framework for reconciling conflicting viewpoints on this issue. This approach also helps to further investigate why factors such as measurement methods, stimulus materials, participants' response modes, processing levels, and attentional load influence visual consciousness patterns. Future research can optimize experimental methods and operations based on these factors, thereby conducting in-depth empirical investigations of this question from the attentional blink perspective.

**Keywords:** visual consciousness patterns, discrete visual consciousness, continuous visual consciousness, attentional blink
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## 1 The Debate Between Discrete and Continuous Modes in Visual Consciousness

Regarding the mode of visual consciousness, some researchers have metaphorically described it as a "switch"that reflects an all-or-none pattern. However, does this all-or-none pattern truly correspond to the actual nature of visual consciousness? Or might visual consciousness possess different levels? This controversial topic has generated substantial evidence from numerous scholars (Förster, 2020). Current major viewpoints can be divided into two categories: (1) the discrete mode (Asplund et al., 2014; Dehaene, 2006; Sergent et al., 2005; Sergent & Dehaene, 2004); and (2) the continuous mode (Cohen et al., 2022; Overgaard et al., 2006; Pretorius et al., 2016; Ramsøy & Overgaard, 2004; Schurgin et al., 2020).

By analyzing previous research on visual consciousness patterns, this paper attempts to explain the causes of these contradictory viewpoints and their influencing factors from an integrated perspective on attentional blink. The goal is to further refine the theory of visual consciousness patterns, provide a compatible theoretical framework for previously conflicting views, and propose specific, feasible experimental operations to address these causes, thereby offering prospects and recommendations for future research.

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## 1.1 The Discrete Mode Perspective

Based on the Global Neuronal Workspace Theory (GNWT), the discrete mode perspective posits that by comparing differences between unconscious and conscious visual processing, researchers can demonstrate the existence of visual conscious experience and measure it. This perspective contains two main claims: (1) unconscious processing is relatively independent, whereas conscious processing involves more semantic-related connections; and (2) information processing is parallel in the unconscious state but serial in the conscious state. Building upon this foundation, the discrete mode perspective proposes that visual consciousness exists in an all-or-none fashion: unconscious processing follows a continuous pattern, but visual consciousness undergoes a nonlinear, dramatic change. Specifically, when stimulus presentation time increases or intensity rises, a threshold emerges in visual consciousness, leading to the coexistence of low and high activation levels. Once a stimulus exceeds this threshold, it suddenly "ignites," activating the global workspace and thereby generating consciousness (Sergent & Dehaene, 2004; Dehaene et al., 2003; Mashour et al., 2020).

From a neuroscience perspective, the global workspace consists of long-range neural connections spanning prefrontal and parietal brain regions, primarily generated by pyramidal neurons in cortical layers II and III, and also includes nonspecific thalamic nuclei, basal ganglia, and some cortical nodes (Förster, 2020; Dehaene & Changeux, 2011). Due to the existence of this threshold, stimuli must first be selected by attention—that is, attention is a necessary prerequisite for visual consciousness, which can only emerge after attentional selection and cannot precede large-scale activation in frontoparietal regions (Dehaene & Naccache, 2001). This suggests that the neural correlates of visual consciousness should have a relatively long latency. Consequently, in Event-Related Potential (ERP) studies, researchers supporting the discrete mode perspective have selected the Late Positivity (LP), which peaks approximately 350 ms after stimulus presentation, as the earliest marker of visual consciousness (Del Cul et al., 2007; Sergent et al., 2005; Seth, 2022). LP represents the difference wave of P3 amplitude between conscious and unconscious conditions. While the source localization and functional significance of P3 remain uncertain, previous research has found that P3 reflects multiple distinct cognitive processes and may therefore have multiple source localizations (Förster, 2020). For the LP component, researchers have used low-resolution electromagnetic tomography to localize it to bilateral frontal, parietal, limbic, cingulate, and temporo-occipital regions (Volpe et al., 2007).

## 1.2 The Continuous Mode Perspective

The continuous mode perspective finds theoretical support in the Reorganization of Elementary Functions and Consciousness (REFCON) theory, based on blindsight and visual subliminal perception research (Overgaard & Mogensen, 2014; Mogensen & Overgaard, 2017), as well as Recurrent Processing Theory (RPT) (Lamme, 2010). Its main arguments are: (1) different hierarchical states exist within visual consciousness; (2) brain region activation is continuous and linear rather than threshold-based and nonlinear; and (3) recurrent processing theory proposes that attention is not a necessary condition for consciousness.

According to REFCON, visual consciousness comprises a high-level hierarchy composed of many different levels of relatively low-level hierarchies. This theory is supported by cognitive neuroscience evidence: brain-damaged patients typically exhibit weakened rather than completely eliminated functions in damaged areas. For example, patients with working memory dysfunction do not completely lose working memory (McAllister et al., 2006); prosopagnosia patients report face stimuli as "some unfamiliar objects" rather than completely ignoring their existence (Oakley & Halligan, 2013); patients with primary visual cortex damage lack subjective awareness of visual stimuli in the damaged area but can still perform discrimination tasks above chance level (Weiskrantz et al., 1974). One study tested blindsight patient GR using the Perceptual Awareness Scale commonly employed in visual consciousness research, finding that GR showed varying degrees of awareness for stimuli (reflected in the distribution of scale scores). This result demonstrates that blindsight is not a complete unconscious state and that visual consciousness possesses different hierarchical structures, supporting the continuous mode perspective (Overgaard et al., 2008).

The main argument of Recurrent Processing Theory is that the brain contains not only feedforward activity from lower to higher areas but also recurrent processing from higher to lower areas (i.e., feedback), with both feedback and feedforward being necessary for visual consciousness generation (Lamme, 2000; Lamme, 2006). Specifically, after stimulus presentation, information is received by the retina and rapidly propagates unidirectionally from lower sensory cortex to higher brain regions. Visual consciousness then emerges when this information reaches lower-level brain areas through feedback transmission. In terms of neural architecture, activation from information spreads from the retina to the primary visual cortex via the lateral geniculate nucleus of the thalamus, then to cortical regions responsible for visual and motor information and the prefrontal cortex. Recurrent Processing Theory posits that attention is not a necessary condition for consciousness; rather, attention only concerns whether stimuli can enter higher levels of the visual system, with visual consciousness emerging when stimuli begin to be processed recurrently.

In human experiments, researchers using binocular rivalry masking paradigms to control face stimulus visibility combined with functional Magnetic Resonance Imaging (fMRI) and Electroencephalogram (EEG) found that visible faces evoked stronger recurrent interactive activity between the fusiform gyrus and early visual areas (Broadman Area 17, BA17) compared to invisible faces (Fahrenfort et al., 2012). Another study using Magnetoencephalography (MEG) combined with masking paradigms and the Perceptual Awareness Scale to localize continuous mode visual consciousness found that occipital activity could reasonably explain variations in scale scores, whereas frontal activity could not, refuting the Global Neuronal Workspace Theory' s claim that frontoparietal regions generate consciousness and supporting Recurrent Processing Theory (Andersen et al., 2016). Similar evidence has been found in other animals: when presenting visual stimuli to experimental monkeys, both aware and unaware conditions elicited similar early neural activity in the primary visual cortex; however, when monkeys were unaware of stimuli, the late component of neural activity in the primary visual cortex (greater than 100 ms) was suppressed. This late component is thought to depend on horizontal and feedback connections, supporting the continuous mode perspective (Hupé et al., 1998; Lamme et al., 1998).

In ERP research, studies on Visual Awareness Negativity (VAN) have more strongly supported the continuous mode perspective, in contrast to those supporting the discrete mode (Eiserbeck, 2022; Roth-Paysen et al., 2022; Seth, 2022). VAN is a difference wave between ERP waveforms evoked under conscious and unconscious conditions within the N1 and N2 time windows, with a latency of approximately 200-500 ms (Koivisto & Revonsuo, 2003; Ojanen et al., 2003). VAN is typically distributed over occipital and temporal electrodes, with stronger amplitude in the hemisphere contralateral to stimulus presentation. Source localization analysis of the VAN component suggests it may be generated along the ventral visual stream, concentrated in the lateral occipital cortex and posterior inferior temporal gyrus (Koivisto et al., 2009; Liu et al., 2012; Pitts et al., 2012; Vanni et al., 1996).

Although LP within the P3b time window has been observed to differ between conscious and unconscious conditions across various paradigms, increasing evidence suggests this difference may not reflect visual consciousness itself but rather relates to whether participants make subjective reports about stimulus identification (Koch et al., 2016). For example, researchers found that when stimulus category reporting was not required, no significant P3 component was generated regardless of whether participants could perceive the stimulus (Cohen et al., 2020). Unlike the debates surrounding LP, literature using multiple paradigms consistently suggests that VAN is the earliest marker of visual consciousness (Förster et al., 2020; Koivisto & Revonsuo, 2010).

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## 2.1 Differences Caused by Different Limiting Mechanisms: The Importance of the Attentional Inhibition Perspective

As contradictory evidence has accumulated, some scholars have proposed that visual consciousness patterns are not purely discrete or continuous but depend on specific experimental parameters (Binder et al., 2017; Derda et al., 2019; Eiserbeck, 2022; Windey & Cleeremans, 2015; Windey, 2013). Paradigm type is an important influencing factor, yet most current research uses perceptual inhibition paradigms (Fu et al., 2017; Koivisto et al., 2017), which suffer from the problem that participants cannot distinguish between "stimulus present but missed" and "stimulus absent" in both subjective judgments and objective tasks. Attentional inhibition paradigms can better circumvent this problem, enabling more precise and detailed investigation of visual consciousness patterns.

Previous research has found that different experimental paradigms yield different consciousness pattern results (Förster et al., 2020; Jimenez et al., 2020). One study investigated visual consciousness patterns using two paradigms (attentional blink and visual masking) and two stimulus types (words and shapes), finding that continuous patterns existed under all conditions, but the proportion of intermediate scale ratings was lowest—meaning participants made the fewest graded response reports—specifically in the attentional blink and word combination condition (Pretorius, 2014). Another study compared word stimulus perception using visual masking versus attentional blink paradigms, showing that participants' consciousness patterns tended toward discrete under attentional blink but more continuous under masking (Sergent & Dehaene, 2004).

Overall, paradigms for studying visual consciousness can be divided into two categories: (1) perceptual inhibition paradigms (contrast reduction, backward masking, and flash suppression); and (2) attentional inhibition paradigms (dual-task, spatial uncertainty, and attentional blink) (Kanai et al., 2010). These two categories differ in their limiting mechanisms for visual consciousness. For instance, attentional blink prevents stimuli from reaching visual consciousness by limiting attention (Raymond et al., 1992), whereas masking reduces conscious visual awareness by interfering with feedback between higher and lower visual areas (Lamme, 2000; Lamme, 2003). Visual consciousness research requires either subjective or objective measurement of consciousness patterns. Due to different limiting mechanisms, in signal detection theory, perceptual inhibition suppresses sensory signals, preventing participants from reporting stimuli, whereas attentional inhibition occurs when participants fail to allocate attention to targets, causing them to miss the stimuli. For perceptual inhibition, participants cannot distinguish between "stimulus present but missed"and "stimulus absent,"whereas in attentional inhibition, participants have different subjective criteria for these two situations and can distinguish between them (Kanai et al., 2010). When using objective measurement, these different limiting mechanisms may similarly cause task performance under perceptual inhibition to approach chance level, whereas performance under attentional inhibition can exceed chance level.

Furthermore, attention and visual consciousness are closely related. Kranczioch et al. (2005) used the attentional blink paradigm to identify activation differences in frontal and parietal regions between targets with and without visual consciousness. As described above, according to Global Neuronal Workspace Theory, attention is a necessary prerequisite for visual consciousness. Its supporters' consciousness network model emphasizes the importance of frontoparietal regions (Dehaene et al., 2006), which are typically associated with attention research. Therefore, some researchers consider attention a necessary mechanism for visual consciousness generation (Rees & Lavie, 2001; Posner, 2012), proposing that attention selects specific information from a continuous stream for processing, resulting in all-or-none visual consciousness outcomes (Vul et al., 2009). In contrast, Recurrent Processing Theory suggests that although attention is not a prerequisite for consciousness, it determines whether information processing can enter deeper stages. While it remains unclear which theory is correct, discussions of visual consciousness inevitably involve the role of attention.

For perceptual inhibition paradigms, extensive previous research has confirmed the coexistence of both visual consciousness patterns (Ramsøy & Overgaard, 2004; Overgaard et al., 2006; Pretorius et al., 2016). However, for attentional inhibition paradigms, evidence is relatively scarce, and existing published studies suffer from issues such as impure measurement results and unclear conceptual definitions. No literature has comprehensively discussed the possibility of both patterns coexisting in this type of paradigm. Therefore, selecting attentional inhibition paradigms to study visual consciousness from the attention perspective will help researchers achieve a more comprehensive understanding of visual consciousness patterns, and investigating whether both patterns exist in attentional inhibition is significant for theoretical integration.

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### 2.2.1 The Attentional Blink Effect and Paradigm

Among attentional inhibition paradigms, attentional blink focuses on time-based attention and makes special contributions to studying visual consciousness patterns from the temporal dimension. The attentional blink effect refers to the temporary impairment in identifying a second target when two targets are presented in rapid succession. This phenomenon was first observed in Rapid Serial Visual Presentation (RSVP) tasks (Raymond et al., 1992). As an attentional inhibition paradigm, the core of attentional blink (also known as the RSVP paradigm) involves rapidly presenting stimuli (e.g., 10 per second) at a fixed spatial location, requiring participants to report one or more targets among several distractors. Previous research shows that although information processing is limited by presentation speed, individuals can still identify most single targets (Broadbent & Broadbent, 1987). However, for dual-target tasks, studies have found that identification of a second target (T2) is impaired when it appears within a 200-500 ms time window after identification of the first target (T1); as the interval between T1 and T2 increases, identification of the second target gradually recovers (Raymond et al., 1992).

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### 2.2.2 The Importance of the Attentional Blink Paradigm

The attentional blink paradigm presents multiple stimuli sequentially within the same spatial location, with high presentation speed and interference from non-target stimuli that can substantially limit information processing. The characteristic that participants' perception of the second target becomes blurred makes attentional blink an excellent tool for studying visual consciousness. Understanding whether the representation of the second target enters consciousness in a discrete or continuous manner helps researchers dissect consciousness patterns.

Compared to other attentional inhibition paradigms (dual-task and spatial uncertainty paradigms), attentional blink can more effectively and finely manipulate visual consciousness by changing task demands and lag times. Specifically, in attentional blink, when participants are only required to perform tasks related to the second target (i.e., single-target task), the complete conscious state of the second target can be measured, as can the distribution of visibility scale ratings without attentional interference (Eiserbeck, 2022). Comparing conditions where the second target is absent versus present helps explore the relationship between rating distributions and discrete mode visual consciousness (Sergent et al., 2005). In dual-target tasks, participants are required to discriminate both the first and second targets: under long-lag conditions, although the first target occupies some attentional resources, the long interval between targets means the attentional blink effect is weak or absent, allowing measurement of participants' consciousness patterns for the second target in this state; under short-lag conditions, the first target occupies substantial attentional resources, severely weakening conscious perception of the second target. Beyond simply distinguishing between long- and short-lag conditions, attentional blink can actually set multiple fine-grained lag times to weaken visual consciousness to varying degrees. Additionally, due to the characteristics of temporal attention, objective task performance in attentional blink gradually improves with increasing lag time. In contrast, in dual-task paradigms, performance degradation is not obvious as the number of items increases from two to eight; spatial uncertainty paradigms only have two conditions for comparison (certain/uncertain) (Kanai et al., 2010). Thus, the characteristic of attentional blink to gradually weaken participants' conscious perception of targets can enhance the effectiveness and precision of exploring visual consciousness patterns, avoiding systematic errors caused by ineffective consciousness weakening or too few comparison conditions.

Studying the time course of visual consciousness is an important approach for evaluating different consciousness theories, making significant contributions to exploring discrete and continuous modes of visual consciousness, and serving as a crucial method for investigating whether attention and consciousness are independent (Förster, 2020; Koivisto et al., 2009; Seth, 2022). Regarding visual consciousness patterns, Global Neuronal Workspace Theory and Recurrent Processing Theory tend to select two different ERP components (LP and VAN) as neural correlates of visual consciousness. Their different latencies—relatively late for LP and early for VAN—are advantageous for explaining corresponding theories, and related empirical research can reveal visual consciousness patterns under specific experimental conditions. By observing temporal relationships between neural correlates of consciousness and attention-related components, researchers can explore the relationship between attention and consciousness. Moreover, compared to spatial inhibition paradigms, attentional blink presents stimuli at the same spatial location, avoiding participants' spatial attention shifts and solving the limitation of spatial inhibition paradigms that can only fix participants' gaze at the central fixation point through instructions, thereby reducing confounding effects from eye movements and exogenous attention on experimental results (Pitts et al., 2014).

## 3 Evidence on Visual Consciousness Patterns from the Attentional Blink Paradigm

Currently, most attentional blink studies have found visual consciousness to be discrete (Asplund, 2004; Sergent et al., 2005; Sergent & Dehaene, 2004), reflected in ERPs as a dichotomous activation pattern of LP. Some researchers have attributed this relatively late neural correlate of consciousness to the attentional blink paradigm itself (Seth, 2022). However, in recent years, consciousness studies using attentional blink have also obtained considerable evidence for continuous patterns, including graded activation patterns of VAN (Eiserbeck, 2022; Karabay et al., 2020; Nieuwenhuis & Kleijn, 2011; Sy et al., 2021; Roth-Paysen et al., 2022). Therefore, this section aims to demonstrate the existence of both visual consciousness patterns in attentional blink and, based on this, further explore factors influencing visual consciousness patterns, thereby proposing specific, feasible experimental operations and recommendations.

### 3.1.1 Behavioral Evidence

In the first study using attentional blink to investigate visual consciousness patterns (Sergent & Dehaene, 2004), participants were required to find French number words with the same number of letters (e.g., DEUX) among a stream of four meaningless capital letter stimuli (excluding QTX) and report their subjective visibility. Researchers designed a continuous subjective scale (21 points) allowing participants to freely choose visibility. This study found that during the attentional blink effect: when the second target was absent, visibility scale scores clustered at the left end, representing "invisible"; when the second target was present, scores clustered at the right end, representing "visible." Therefore, researchers concluded that visual consciousness patterns are discrete.

Building on this, researchers designed other methods to measure visual consciousness. Post-Decisional Wagering (PDW) requires participants to bet on the correctness of their decisions after making them. If the decision is correct, they win the money bet; if incorrect, they lose it. This method allows more implicit introspective reporting while avoiding participants' tendency to ignore the 0 point on scales—that is, preserving minimal visual consciousness for weak stimuli. When researchers required participants to use PDW for word stimuli, the results revealed a discrete consciousness pattern (Nieuwenhuis & Kleijn, 2011). Some studies have argued that subjective report results are unreliable and therefore proposed an objective measurement method with related hypotheses (Asplund, 2014). This study suggested that under short-lag conditions, the precision of identifying the second target should be affected, gradually recovering as the interval between the first and second targets increased, showing a continuous pattern. In two experiments using color and face materials, participants were required to select responses on color and "face wheels," with precision reflected by the angle between the selected color on the wheel and the correct answer. However, results showed that precision did not change significantly with the interval between the first and second targets. Therefore, the study concluded that visual consciousness emerges in an all-or-none state.

Additionally, researchers manipulated features (color and orientation) and task types of the first and second targets to explore how precision and guessing rates change, using the same standard mixture model as Asplund (2014). Results found that when tasks required participants to attend to different features between two distinct targets (i.e., attentional set switching), conscious perception of the second target was weakened in an all-or-none manner, manifested as a significant increase in guessing rate (Sy et al., 2021). Another study (Karabay et al., 2020) compared the classic attentional blink paradigm, bilateral attentional blink paradigm (presenting two stimulus streams simultaneously on both sides of fixation), and a paradigm where bilateral attentional blink occurred at the second position after the first target. It found that when the first target appeared only in a single location, regardless of whether the second target' s location was fixed or variable, participants showed guessing rate effects in target identification—that is, visual consciousness exhibited a discrete pattern.

### 3.1.2 ERP Evidence

Sergent et al. (2005) used the same experimental design as Sergent and Dehaene (2004) to investigate ERP differences between different subjective visibility ratings. The study found that visibility ratings showed a bimodal distribution (clustering at both ends of the scale) and identified a dichotomous activation pattern within the P3b (LP) time window, concluding that the way stimulus information enters visual consciousness in attentional blink is all-or-none. However, the researchers also found a continuous activation pattern within the N2 time window (the earliest component showing visibility rating differences). Based on the bimodal distribution of scale ratings in behavioral data and Global Neuronal Workspace Theory, they interpreted the graded activation pattern observed in N2 as reflecting the unconscious processing stage—that is, unconscious processing can be continuous, but entry into visual consciousness is all-or-none (Sergent et al., 2005).

### 3.2.1 Behavioral Evidence

Previous studies using different stimulus materials have obtained corresponding evidence supporting continuous patterns. For example, one study used faces as stimulus material, requiring participants to perform gender discrimination on the second target and rate its visibility using a 4-level Perceptual Awareness Scale (Eiserbeck, 2022). Results showed that the proportion of intermediate responses on the subjective scale was higher than responses at both ends (levels 2 and 3), with significant differences between each level and subjective ratings increasing with visibility. This indicated that under these conditions, researchers found a continuous pattern of visual consciousness. Additionally, experiments using words and characters found that when word materials were replaced with character materials, the scale rating distribution became continuous—that is, visual consciousness showed a continuous pattern, opposite to results obtained with word stimuli (Nieuwenhuis & Kleijn, 2011).

Experiments manipulating target stimulus features and controlling their spatial locations also reached continuous pattern conclusions. As described in section 3.1.1, the study by Sy et al. (2021) further found beyond the discrete pattern results that when two targets shared the same visual feature (orientation), participants' precision in perceiving the second target decreased, and visual consciousness showed a continuous pattern. Therefore, researchers proposed that visual processing affects visual consciousness when attentional resources are competed for, and that attentional set switching can reconcile evidence for the two different visual consciousness patterns. Regarding spatial location experiments, when the first target' s location could change (i.e., randomly appear on the left or right side), visual consciousness patterns were continuous (Karabay et al., 2020). Based on this, researchers proposed the Adaptive Gating Hypothesis: when attention needs to monitor multiple spatial locations simultaneously, the attentional focus range is larger, the threshold for visual consciousness is lowered, and visual consciousness forms a continuous pattern; when attention only needs to concentrate on one spatial location, the attentional focus range is smaller, and visual consciousness exhibits a discrete pattern.

### 3.2.2 ERP Evidence

Selecting different ERP components as consciousness indicators (VAN or LP) leads to different conclusions about visual consciousness patterns. Eiserbeck (2022) also studied ERP amplitude differences between different visibility ratings, finding significant differences between ERP amplitudes based on adjacent visibility ratings within the N1, N2, and P3 time windows—that is, a continuous pattern of visual consciousness was found in ERP analysis. The researcher explained that the extensive and continuous negative component found in the N1 and N2 time windows could be interpreted as the VAN component and considered it a marker of visual consciousness, a conclusion opposite to previous research (Sergent et al., 2005). Additionally, a continuous change pattern was also found in the P3 time window, which the researcher suggested might reflect different hierarchical levels of visual consciousness.

Another study used face materials and an adjusted Perceptual Awareness Scale, manipulating the contrast of the second target inside (short-lag) and outside (long-lag) the attentional blink effect window to make the proportions of visible and invisible trials statistically equal inside and outside the window, thereby exploring early and late electrophysiological correlates of visual consciousness. Through linear mixed-model analysis and Bayesian repeated-measures ANOVA, researchers found that N170, VAN, and P3b amplitudes were enhanced in visible compared to invisible trial conditions and changed linearly with visibility ratings, indicating that both early (N170, VAN) and late (P3b) mechanisms of visual consciousness inside and outside the attentional blink window are similar and both are continuous patterns (Roth-Paysen et al., 2022).

## 4 The Influence of Measurement Methods, Stimulus Materials, and Experimental Tasks in Attentional Blink

Based on the aforementioned contradictory results, visual consciousness patterns under attentional blink are not purely discrete or continuous. Through enumerating and discussing these studies, this paper demonstrates the possibility of both visual consciousness patterns coexisting in attentional blink. This section explores from multiple dimensions how specific experimental factors—measurement methods, stimulus materials, and experimental tasks (including task-defined response modes, different processing levels required by tasks, and attentional load)—influence visual consciousness pattern results, while noting existing inadequacies in current research regarding exploration of these factors.

### 4.1.1 The Nature and Indirectness of Subjective Measurement

Subjective scales are commonly used measurement methods in consciousness research, typically judging visual consciousness patterns by examining the proportion of intermediate rating scale usage. However, the inherent properties and characteristics of scales themselves can guide corresponding visual consciousness patterns, thereby influencing experimental results. Simultaneously, subjective measurement methods have indirectness and may incorporate other factors (such as risk aversion) affecting participants' choices. For instance, the intervals on a 21-point scale are too fine-grained, making people less inclined to use such precise rating levels. Additionally, the feature that only the endpoints are labeled leads people to use intermediate responses less frequently (Overgaard et al., 2006). Moreover, using a 21-point scale results in lower sensitivity to continuous visual consciousness (proportion of intermediate responses) compared to 7-point or 4-point scales (Pretorius, 2016). Compared to 7-point scales, 4-point scales have higher validity and have been named the "Perceptual Awareness Scale" (PAS), becoming a commonly used subjective measurement method in consciousness-related fields (Ramsøy & Overgaard, 2004).

Regarding the PDW method used in the aforementioned study (Nieuwenhuis & Kleijn, 2011), it should be noted that this measurement method is not pure. Its indirectness leads to other factors influencing participants' choices, such as risk aversion. Some researchers argue this is actually a decision-making behavior rather than pure reporting (Wierzchoń et al., 2014).

### 4.1.2 Limitations of Objective Measurement Content

Some researchers argue that subjective measurement is overly influenced by non-experimental factors and therefore choose objective measurement methods. However, objective measurement typically assesses different aspects of visual consciousness, and single measurements of visual consciousness patterns are similarly limited. Current research has only objectively measured stimulus encoding precision (Asplund, 2014). Clarifying what each measurement method corresponds to is necessary for understanding visual consciousness patterns from multiple angles. However, it should be noted that precision in stimulus identification does not necessarily equate to visibility in conscious perception (Asplund, 2014)—that is, objective behavioral indicators do not equal complete subjective experience, and different results may emerge in other dimensions (perceived intensity and duration).

## 4.2 Stimulus Materials

Stimuli used in visual consciousness research include characters, words, faces, etc., and the inherent discrete or continuous properties of stimulus materials themselves affect research results. For example, when using number words as materials, participants must first identify which item in the attentional blink sequence is a number word before assessing its subjective visibility. If participants only perceive part of the number word, they cannot identify it as a number word, leading to incorrect reports (Elliott et al., 2016). Additionally, researchers have noted that word stimuli have inherent discrete properties—participants need to first identify the second target as a word (distinguishing it from distractors) before making visibility ratings. When they switched to face materials, they obtained continuous consciousness pattern results (Eiserbeck, 2022; Roth-Paysen et al., 2022). Therefore, for some materials, their continuous (or discrete) properties can be reduced or altered through technical means to explore how material continuity affects visual consciousness patterns.

## 4.3 Response Modes

The impact of participants' response modes (continuous or dichotomous) on visual consciousness patterns remains controversial and is closely related to material processing levels. For stimuli such as line segments and colors, typical experimental tasks use continuous physical response devices (gratings, color wheels, etc.) for participant responses (Asplund, 2014; Elliott, 2016), which may lead participants to 倾向于 continuous response modes. For materials like words and faces, researchers generally use classification (or discrimination) tasks (Eiserbeck, 2022). These continuous or dichotomous tasks constrain participants' response methods and may similarly constrain the obtained visual consciousness patterns. It remains unclear to what extent using different task types and response modes affects experimental results, so future research could attempt to separately explore the influence of material processing levels and response modes.

### 4.4 Processing Levels

The Levels of Processing (LoP) hypothesis is a theory about the transition from unconscious to conscious visual experience, proposing that continuous perception occurs for low-level stimulus representations (i.e., stimulus "energy" or "feature" level), while dichotomous perception occurs for high-level stimulus representations (i.e., perception of "letters," "words," or "meaning" ) (Windey, 2013; Windey & Cleeremans, 2015). Although this hypothesis has obtained some supporting evidence (Binder et al., 2017; Derda et al., 2019), controversies remain. For example, in low-level tasks, sometimes Perceptual Awareness Scale ratings cluster in the middle with no significant accuracy differences, while sometimes ratings cluster at both ends with significant accuracy differences (Jimenez, 2020). Some researchers consider gender tasks a type of low-level processing task, which would produce continuous visual consciousness patterns, but gender may also correspond to higher-level social categorization that might require high-level cognitive judgment to some extent (Eiserbeck, 2022). Therefore, future research using face stimuli should clearly define low-level and high-level tasks.

### 4.5 Attentional Load

Both the Adaptive Gating Hypothesis and Attentional Set Theory studies indicate that attentional changes lead to different visual consciousness patterns (Karabay et al., 2020; Sy et al., 2021). The Adaptive Gating Hypothesis studies visual consciousness patterns from the perspective of spatial attention, while Attentional Set Theory explains visual consciousness patterns from the perspective of feature attention. Regarding the specific mechanisms of how attention affects visual consciousness, more evidence is needed. However, based on current results, when attentional focus range increases (i.e., participants simultaneously monitor multiple spatial locations) or attention shifts between different features (attentional set switching)—that is, when attentional load increases—results tend to shift from discrete to continuous patterns.

The Adaptive Gating Hypothesis is limited to single and double spatial locations and does not provide more precise definitions of attentional focus. Additionally, when the first and second targets appear close in time, the "focus"effect produced by the first target may cover not only the second target but also distractors near it (Karabay et al., 2020). Future research should establish operational definitions of attentional focus and exclude the influence of distractors on visual consciousness patterns.

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## 5 Summary and Future Directions

In summary, because paradigm type influences visual consciousness patterns to some extent, studying visual consciousness patterns in attentional blink paradigms can help researchers more comprehensively understand the nature of visual consciousness. Current results indicate that visual consciousness patterns in attentional blink are not purely fixed in one mode. Measurement methods, stimulus materials, response modes, processing levels, and attentional load all influence measured visual consciousness patterns to varying degrees. Future research could explore and determine their respective weights.

Regarding measurement methods, using subjective reports may yield confounded results from multiple factors (such as risk aversion) or produce incorrect introspective reports (such as misperception), or even misunderstanding of instructions—for example, interpreting "visibility" as "clarity of gender" (Eiserbeck, 2022). Meanwhile, although Perceptual Awareness Scale ratings are generally considered the most sensitive subjective visual consciousness indicator, their validity within the Levels of Processing framework is controversial—that is, PAS is considered more suitable for measuring low-level stimuli (Jimenez et al., 2020). Using objective measurement may fail to discover some implicit perception cases, such as when participants report no visual consciousness of stimuli but demonstrate above-chance accuracy in forced-choice stages, and objective measurement indicators cannot fully reflect subjective experience. This content limitation means that when using objective methods to measure consciousness patterns, it is necessary to clarify which specific aspect of consciousness patterns is being measured. The influence of stimulus material properties on visual consciousness patterns has been demonstrated in previous research (Elliott et al., 2016; Nieuwenhui & Kleijn, 2011). For material properties, low-level stimuli such as line segments and orientations tend to produce more continuous visual consciousness, while semantic stimuli like words produce more discrete patterns (Jimenez et al., 2020). Additionally, Eiserbeck's (2022) finding of differences in N1 is also related to material differences—significant differences exist between word and face materials (Aranda et al., 2010), with face changes causing significant amplitude variations in the N170 component.

On the other hand, although the Levels of Processing hypothesis provides a new accommodating framework for different evidence on visual consciousness patterns, sufficient supporting evidence is still lacking. Moreover, when using face stimuli, definitions of low-level and high-level tasks are not clearly distinguished. Processing levels are also closely related to participants' response modes —simple judgment tasks are more often used for high-level stimuli, while continuous response devices are used in low-level stimulus experiments. The influence of this response mode on patterns is currently unclear. Regarding attentional load, both the Adaptive Gating and Attentional Set Switching theories explore how attention affects visual consciousness patterns from different perspectives, but both lack more precise definitions—for example, the Adaptive Hypothesis only manipulates single or double spatial location factors without further investigating parameters like distance between possible first target locations, and the materials used (line segments) are low-level stimuli, with no empirical support for whether the same effect exists for high-level stimuli. Therefore, future research needs to consider the interaction between stimuli and spatial locations. Attentional Set experiments focus on target similarity at the feature dimension, while future studies could explore target similarity at higher-level processing dimensions such as semantic dimensions—for example, using words that are semantically similar and dissimilar (car-bike; car-apple), hypothesizing that visual consciousness shows continuous patterns when the first and second targets are similar, and discrete patterns when they are dissimilar due to attentional set switching.

From a neuroscience perspective, exploring neural correlates of consciousness still requires systematically testing specific hypotheses about the nature of visual consciousness by integrating different neural theories. Sergent et al.'s (2005) experiment found differences in N2 and P3. Although researchers interpreted N2 as preconscious processing based on Global Neuronal Workspace Theory, according to Recurrent Processing Theory, the observed N2 activity could be considered to reflect conscious but fragile large-capacity representations—that is, continuous visual consciousness—while P3 activity might reflect the formation of stable limited-capacity representations, that is, the consciousness part related to access and reporting, which depends on attentional selection and is thought to occur in an all-or-none manner (Eiserbeck, 2022). Additionally, the continuous pattern of P3 found by Eiserbeck (2022) is not compatible with either Global Neuronal Workspace Theory or Recurrent Processing Theory, with researchers preferring to explain it using REFCON theory. Evidently, different theoretical choices lead to different data interpretations, but currently many studies use theories post-hoc to explain results rather than making a priori critical predictions (Yaron et al., 2022). Therefore, more research is needed to clarify relationships between various theories and empirically distinguish, compare, test, and develop them (Seth, 2022) to further explore visual consciousness patterns.

Furthermore, current ERP research on visual consciousness patterns in attentional blink is limited, and the brain localization of discrete or continuous consciousness patterns is not precise enough. Therefore, future studies could incorporate Magnetoencephalography, whose high spatiotemporal resolution can both meet the strict temporal precision requirements of attentional blink paradigms and relatively accurately localize brain sources, facilitating exploration of neural correlates of visual consciousness and helping researchers achieve deeper understanding of visual consciousness patterns.

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