Anticipated Relevance Modulates Early Visual Processing

Lasse Dietz (l.dietz1@uu.nl)*

Samson Chota*

Kabir Arora*

Stefan van der Stigchel*

Christoph Strauch*

Surya Gayet*

*Experimental Psychology, Helmholtz Institute, Utrecht University
Heidelberglaan 1, 3584 CS Utrecht, The Netherlands

Abstract

Finding objects in our environment involves comparing visual input with memory representations to prioritize relevant over irrelevant visual input. In dynamic environments, relevance can change. Anticipating relevant visual events allows the visual system to allocate resources efficiently. We examined how predictable changes in stimulus relevance affect memory-guided visual processing. Participants memorized an oriented grating and a cue indicated which of two sequentially presented probes was relevant for a memory match/mismatch judgment. First, using rapid invisible frequency tagging (RIFT), we imperceptibly modulated the luminance at the stimulus location with 60Hz, inducing a corresponding oscillatory response in the occipital electrodes of the EEG signal. We found an increased RIFT response -reflecting that early visual processing intensified- before the presentation of relevant compared to irrelevant probes. Second, using multivariate pattern analyses, we found that memory-matching and memory-mismatching probes evoke a more distinct neural response when they are task-relevant compared to irrelevant. Together, these findings demonstrate that anticipating the relevance of upcoming events enables the visual system to prepare visual processing for efficient memory-guided visual selection.

Keywords: Human Vision; Temporal Visual Processing; Visual Working Memory; Temporal Expectations; Rapid Invisible Frequency Tagging; MVPA

Introduction

Finding objects in the environment entails processing visual input and subsequently comparing it to a memory template. Numerous studies have demonstrated that visual working memory (VWM) content modulates visual processing (Gayet et al., 2017, 2013; Olivers et al., 2006; Hollingworth et al., 2013; Scocchia et al., 2013). Using memory to guide visual processing helps us to filter relevant information from the outside world. The world is dynamic, however, and what is relevant now may not be relevant later. For example, a highway sign announcing a gas station is not relevant while the tank is full but will be relevant once the tank is nearly depleted. Anticipating when visual input is relevant and when it is not allows the visual system to distribute processing resources efficiently over time, leading to improved behavioral performance and minimizing metabolic cost (Coull & Nobre, 1998; Heuer & Rolfs, 2022; Nobre & Van Ede, 2018; Vangkilde et al., 2012; Rohenkohl et al., 2012; Miniussi et al., 1999). Here, we investigated how predictable changes in stimulus relevance influence memory-guided visual processing. Specifically, we hypothesized (1) visual processing to intensify in anticipation of upcoming relevant events and, (2) subsequently, memory content to modulate the neural response to relevant visual events more strongly than to irrelevant events.

Methods

Participants memorized an oriented grating, followed by a cue indicating which of two sequentially presented probes was relevant for a memory match/mismatch judgment (Figure 1A - Participant View). Since stimulus changes (cue, orientation, etc) were counterbalanced within participants, and the temporal structure of a trial was fixed, relevant and irrelevant probes were physically identical across trials and only differed in terms of task relevance. To investigate differences in early visual processing, this study employed rapid invisible frequency tagging (RIFT). Specifically, we modulated the luminance of the screen at 60Hz (imperceptible to participants) at the stimulus location, thereby inducing a corresponding oscillatory response (measured via coherence) in the EEG signal (Figure 1A - Projector View). Moreover, we used support vector machine classification to compare the multivariate response patterns to memory-matching versus mismatching probes.

Results

The results support both hypotheses. First, enhanced sensory processing (as measured via RIFT coherence) was found before the presentation of a relevant probe compared to an irrelevant probe. Specifically, in the interval preceding both probe 1 and 2, RIFT coherence was larger before a relevant probe than when that same probe was irrelevant (Figure 1B). This shows that visual processing intensified in anticipation of a relevant visual event. Second, while memory-matching and memory-mismatching visual events consistently yielded dissociable neural response patterns,

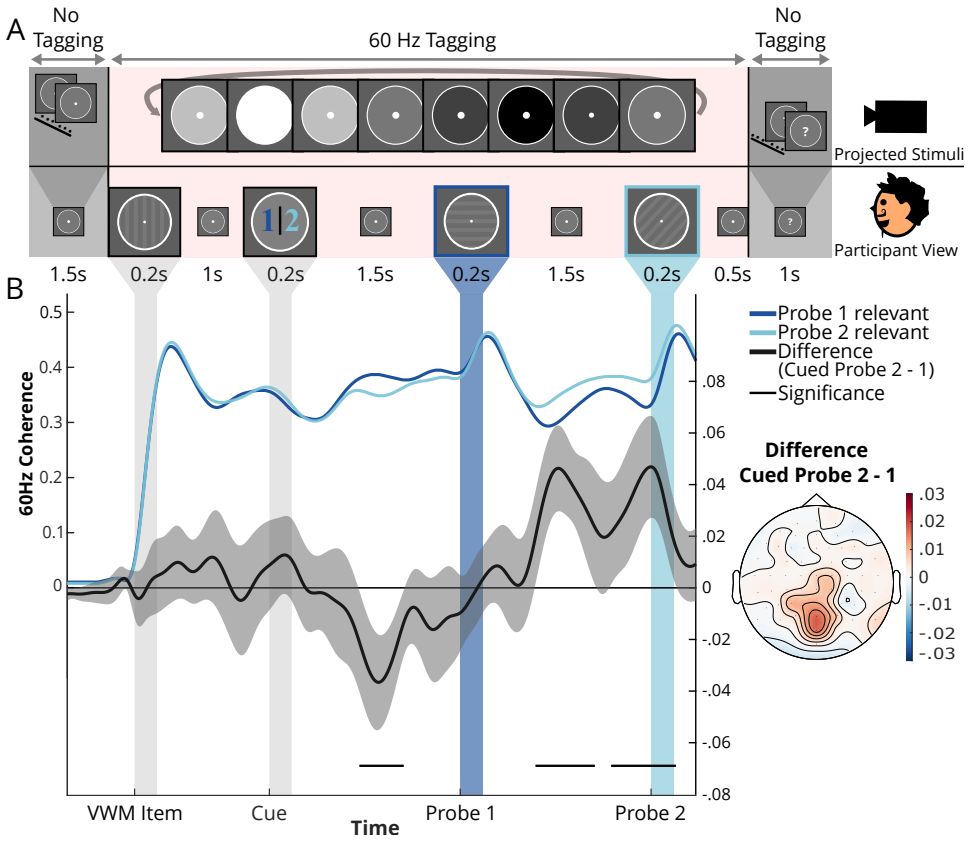

Figure 1: (A) Top row: Luminance changes of a single RIFT cycle presented continuously at 60Hz throughout the entire trial, here visualized for the fixation period. The bottom row displays the visual events as perceived by the participants. (B) Average RIFT coherence (quantifying visual processing intensity) over time, separated for trials in which probe 1 (dark blue) or probe 2 (light blue) was relevant. The black line depicts the paired difference between conditions (shaded area: 95% confidence interval). Horizontal lines indicate significance using a permutation-based cluster analysis, $p < .05$.

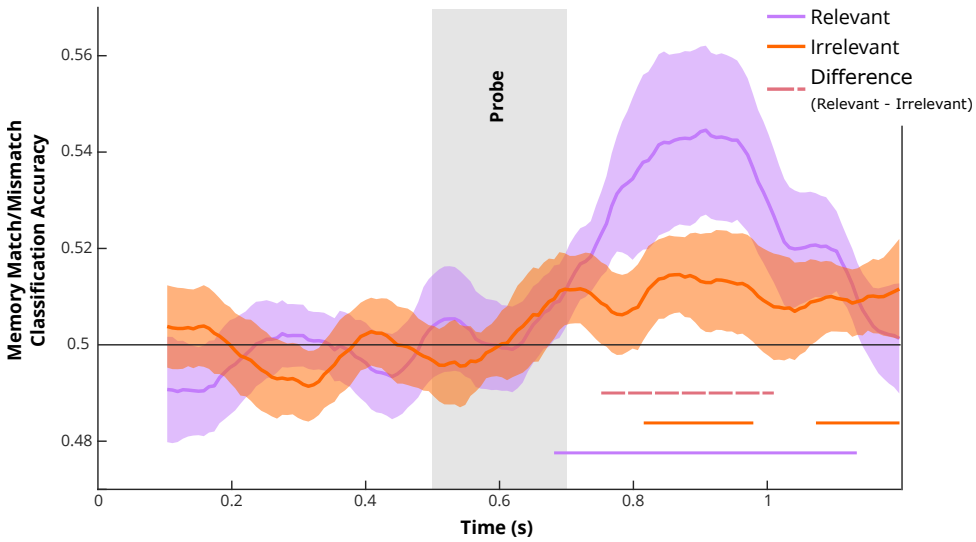

Figure 2: Multivariate classification performance between memory-matching and memory-mismatching probes, separated for relevant (purple) and irrelevant (red) probes, collapsed across probes 1 and 2 (shaded area: 95% confidence interval). Horizontal lines indicate significance using a permutation-based cluster analysis. The dashed line represents significantly higher classification accuracy for the relevant over the irrelevant condition, $p < .05$.

these neural patterns were substantially more distinct (i.e., better classification accuracy) for relevant probes (Figure 2). This indicates that memory content modulated the visual response to the probes more strongly for relevant probes than for irrelevant probes.

Discussion

We demonstrate that the anticipated relevance of a visual event (1) enhances early visual processing prior to event onset and (2) subsequently enhances the memory-guided differentiation between memory matching and mismatching visual events. Thus, anticipating the relevance of upcoming events enables the visual system to prepare visual processing for efficient memory-guided visual selection.

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