Peer Community In Registered Reports

Does pupil size track high-level attention?

*A recommendation by **D. Samuel Schwarzkopf** based on peer reviews by **Sander Nieuwenhuis** and **Martin Rolfs** of the STAGE 2 REPORT:*

Ana Vilotijević, Sebastiaan Mathôt (2024) The effect of covert visual attention on pupil size during perceptual fading. OSF, ver. 2, peer-reviewed and recommended by Peer Community in Registered Reports.
https://osf.io/ku8qc?view_only=f331df53b50f431386fabba9e386b387

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Schwarzkopf, D. (2024) Does pupil size track high-level attention?. *Peer Community in Registered Reports*, 100888. 10.24072/pci.rr.100888

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Higher-level cognitive processes like attention, memory, or mental imagery can produce pupil responses, without any actual difference in luminance of the visual stimulus. Interestingly, the inverse scenario remained untested to date: when a physical luminance difference is perceptually eliminated from awareness, does pupil size still track attention to the stimulus? In this Registered Report, Vilotijević and Mathôt (2024) sought to test this experimentally using a perceptual fading phenomenon where two Gaussian patches with different luminances fade from consciousness and are thus perceived as mid-level uniform grey (or at least the subjective difference is much reduced). This fading manipulation, as well as a control condition without perceptual fading, were presented in separate blocks. Participants were instructed to covertly attend one of the patches.

The authors hypothesised that if pupil size reflects attentional selection, these pupil responses in the fading condition should be eliminated or at least reduced, and this should evolve with time as the stimuli are perceptually fading. Their results show that pupil responses during covert attention are indeed reduced during perceptual fading - but they are not eliminated. Interestingly, this reduction did not depend on time or self-reports of the strength of perceptual fading. The findings therefore suggest that pupil dilation tracks subjective brightness differences. One inherent issue with experiments like these is that the experimental and control conditions necessarily involve a physical difference in the stimulus. Here, the fading condition had the same spatial configuration of light and dark stimuli throughout a block while in the control (non-fading) condition the light and dark stimuli alternated sides between trials. It is therefore impossible to completely rule out that the physical difference affects the results. However, the only alternative to this would be an experimental design in which the stimuli never change, but only the subjective perceptual state varies. Such a design is completely at the mercy of the participant's subjective state and therefore loses experimental control and statistical sensitivity. The present results confirmed the authors' prediction that there are indeed differences in

overall pupil responses during the fading and control conditions, irrespective of covert attention. Critically, the fact that the attention effect did not vary with time or subjective self-reports of the illusion supports the authors' interpretation that this reflects higher-level cognition: the mere act of attending to the dark side - even if the actual appearance has faded - could cause a sustained pupil dilation. This would be consistent with the type of pupil effects for memory and mental imagery that motivated the present study. However, a simpler alternative is that the experience of perceptual fading was incomplete (as possibly suggested by Figures 2D and 2F) but that self-reports fail to capture this subjective experience accurately. Perhaps a future study could compare the magnitude of the attentional pupil effects when the initial stimulus is completely removed. If similar differences in pupil response persist this would suggest that the present results are due to high-level modulation or the residual low-level luminance difference. The Stage 2 manuscript was evaluated by two reviewers and the recommender over two rounds of review. One reviewer again advised additional robustness checks to rule out eye movement confounds, an issue they had already raised during Stage 1 review. The researchers provide clear evidence that this is unlikely to have confounded their findings. This has been added to the supplementary data repository. Following this review and revision, the recommender judged that the Stage 2 criteria were met and awarded a positive recommendation. **URL to the preregistered Stage 1 protocol:** https://osf.io/bmtp6 **Level of bias control achieved:** Level 6. *No part of the data or evidence that was used to answer the research question was generated until after IPA.* **List of eligible PCI RR-friendly journals:**

- Advances in Cognitive Psychology
- Collabra: Psychology
- Cortex
- Experimental Psychology
- Journal of Cognition
- Peer Community Journal
- PeerJ
- Psychology of Consciousness: Theory, Research and Practice
- Royal Society Open Science
- Studia Psychologica
- Swiss Psychology Open

References:

1. Vilotijević, A. & Mathôt, S. (2024). The effect of covert visual attention on pupil size during perceptual fading [Stage 2]. Acceptance of Version 2 by Peer Community in Registered Reports. https://osf.io/ku8qc?view_only=f331df53b50f431386fabba9e386b387

Reviews

Evaluation round #1

DOI or URL of the preprint: **https://osf.io/m7g4a?view_only=8bc552d2d4c34017adf87cf396b3ea9c**
Version of the preprint: 1

Authors' reply, 24 September 2024

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Decision by D. Samuel Schwarzkopf, posted 22 September 2024, validated 23 September 2024

Please submit a revision of the Stage 2 manuscript

Dear authors

Your Stage 2 manuscript has now been reviewed by two of the original reviewers.

Before I get to their comments, I point out a bigger procedural issue: you integrated parts of your Stage 1 Methods ("Data analysis and preprocessing") into your Stage 2 Results and this has led to significant changes to the text. Unfortunately, this is not really acceptable. I appreciate why you did this: You are describing the methodology as you present results but unfortunately **this confounds comparison with the preregistered version**. Ideally you should revert back the methods as they were in the Stage 1 version that received In-Principle Acceptance. Arguably, it could be acceptable to start the Results section at the point where you describe testing the individual hypotheses (page 20 in the IPA version). Note that your approach seems to be above board to me; it is largely a matter of facilitating comparison between the preregistration and the final article.

The two reviewers are generally very positive. One of them has some suggestions for improving the clarity and delving deeper into what the data might mean. Further exploration of the data are theoretically optional but the reviewer's suggestion is sensible, so while it is optional to go beyond analyses preregistered in Stage 1 I would encourage you to add this.

Given the positive comments by reviewers, ideally you can make these changes without necessitating a further round of external review. Please contact me directly with any questions about the approach to take here and we can perhaps arrive at a reasonable compromise between having a good narrative flow and a robust separation of the preregistered methods.

Sam Schwarzkopf

Reviewed by Sander Nieuwenhuis, 23 August 2024

This is a rigorous and very well written stage 2 report. I have no suggestions on how to further improve this manuscript. I also confirm that:

- The data are able to test the authors' proposed hypotheses.
- The introduction, rationale and stated hypotheses are the same as the approved Stage 1 submission.

- The authors adhered precisely to the registered study procedures.

- The authors' conclusions are justified given the evidence.

Reviewed by Martin Rolfs, 22 September 2024

Declaration regarding possible conflict of interest: The manuscript now includes an additional author, Arne Stein, who was a research assistant and thesis student in my lab. I am currently co-supervising his Master's thesis. I was not aware of this new collaboration when I accepted the Stage 2 review. I will provide my assessment nevertheless (and I believe it is impartial), but wanted to make this potential conflict of interest transparent to everyone involved.

This is a very neat manuscript. The introduction is clearly written and shows good scholarship. The experiments are very convincing and the hypotheses cover a range of interesting questions. Small deviations from the analysis plan have been appropriately highlighted and explained.

The results are very clear, and all sanity checks were successful: The initial pupil response is largely absent in the fading trials compared to a strong response in the non-fading trials (resulting in overall larger pupil size, in line with Hypothesis 2). Attending a specific location significantly modulated the pupil response (smaller pupil when the brighter stimulus was attended; Hypothesis 1) and accuracy was higher at the attended compared to the unattended location (Hypothesis 6). The rest of the results were also decisive and quite exciting — the impact of covert attention was smaller but still quite substantial in the condition in which the stimulus faded compared to the non-fading condition and this effect was independent of perceptual experience of fading strength. Overall, this paper will make an interesting contribution to the literature on cognitive influences on pupil size and on the relation between perception and oculomotor

I have some suggestions:

1. It is my understanding that the data in Figure 2D include only trials from fading blocks. If that is correct, then it should be highlighted in Figure 2D's caption. If this understanding is not correct, it would be good to separate them for the fading vs non-fading blocks. In any case, it would be useful for readers to see a report/figure of the distributions of fading self-reports in those two types of blocks.

2. The authors conclude that the impact of covert attention on pupil size is modulated by stimulus luminance even when the subjective experience of brightness is substantially reduced. Did pupil size have the same chance of being altered in the two conditions? There is a limit to how strongly pupil size can increase or decrease. Could it be that these limits were closer to the observed pupil size in the conditions in which subjects experienced fading? If so, it could explain the smaller effect of covert attention in that condition. What are the arguments against this possibility?

3. The last line on page 33 of the submitted document reads "for example when making an eye movement to the dark or bright spots". I am not sure what the authors want to say here and why they bring up eye movements in this context.

4. As I have pointed out every time: Given that saccades and blinks strongly contribute to counteracting fading, it would be great to see an analysis of eye movements (number of blinks and saccades and saccade amplitude distribution) as a function of reported fading in both blocks.