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Is the N2pc a correlate of attentional selection? An #EEGManyLabs multi-lab registered replication of Eimer (1996)

A recommendation by **Maxine Sherman**  based on peer reviews by **Clayton Hickey** and **Reny Baykova** of the STAGE 2 REPORT:

Martin Constant, Ananya Mandal, Dariusz Asanowicz, Bartłomiej Panek, Ilona Kotlewska, Motonori Yamaguchi, Helge Gillmeister, Dirk Kerzel, David Luque, Sara Molinero, Antonio Vázquez-Millán, Francesca Pesciarelli, Eleonora Borelli, Hanane Ramzaoui, Melissa Beck, Bertille Somon, Andrea Desantis, M. Concepción Castellanos, Elisa Martín-Arévalo, Greta Manini, Mariagrazia Capizzi, Ahu Gokce, Demet Özer, Efe Soyman, Ece Yilmaz, Joshua O. Eayrs, Raquel E. London, Tabitha Steendam, Christian Frings, Bernhard Pastötter, Bence Szaszko, Pamela Baess, Shabnamalsadat Ayatollahi, Gustavo A. León Montoya, Nicole Wetzel, Andreas Widmann, Liyu Cao, Xueqi Low, Thiago L. Costa, Leonardo Chelazzi, Bianca Monachesi, Siri-Maria Kamp, Luisa Knopf, Roxane J. Itier, Johannes Meixner, Kerstin Jost, André Botes, Carley Braddock, Danqi Li, Alicja Nowacka, Marlo Quenault, Daniele Scanzi, Tamar Torrance, Paul M. Corballis, Gianvito Laera, Matthias Kliegel, Dominik Welke, Faisal Mushtaq, Yuri G. Pavlov, Heinrich R. Liesefeld (2025) A multilab investigation into the N2pc as an indicator of attentional selectivity: Direct replication of Eimer (1996). PsyArXiv, ver. 3, peer-reviewed and recommended by Peer Community in Registered Reports.

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In attention research, the N2pc ERP – a lateralised negative deflection over parieto-occipital electrodes – is often interpreted as a marker of attentional selection, so much so that it is frequently used a tool in the attention literature for inferring that a stimulus was attentionally processed. This interpretation of N2pc has its roots in the seminal work of Eimer (1996), wherein the N2pc was observed when participants performed an attentional selection task with either colour or form (letter) stimuli. Despite its enormous influence in

attention research, this work has never been directly replicated. Here, Constant et al. (2025) conducted a high-powered replication attempt of the critical Study 2 of Eimer (1996), as part of the #EEGManyLabs (Pavlov et al., 2021) project. Twenty two labs across 14 countries took part and the N2pc was tested for using four pre-registered and one exploratory pipelines. Results showed that the N2pc for form stimuli was remarkably robust, replicated by every participating lab under all four pre-registered (and one exploratory) preprocessing pipelines. By contrast, the N2pc for colour stimuli did not technically replicate, though a negative deflection was found 70ms earlier than originally reported. This is a gold-standard replication attempt that should be an invaluable resource to the selective attention field. The Stage 2 manuscript was evaluated over one round of in-depth review by two reviewers who also reviewed the Stage 1 report. Based on detailed responses to the reviewers' comments, the recommender judged that the manuscript met the Stage 2 criteria and awarded a positive recommendation. **URL to the preregistered Stage 1 protocol:** <https://osf.io/dw68r>

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](#)
- [Brain and Neuroscience Advances](#)
- [Collabra: Psychology](#)
- [Cortex](#)
- [F1000Research](#)
- [Imaging Neuroscience](#)
- [In&Vertebrates](#)
- [Journal for Reproducibility in Neuroscience](#)
- [Meta-Psychology](#)
- [Neuroimage: Reports](#)
- [Peer Community Journal](#)
- [Royal Society Open Science](#)
- [Studia Psychologica](#)
- [Swiss Psychology Open](#)

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1. Constant, M., Mandal, A., Asanowicz, D., Panek, B., Kotlewska, I., Yamaguchi, M., Gillmeister, H., Kerzel, D., Luque, D., Molinero, S., Vázquez-Millán, A., Pesciarelli, F., Borelli, E., Ramzaoui, H., Beck, M., Somon, B., Desantis, A., Castellanos, M. C., Martín-Arévalo, E., Manini, G., Capizzi, M., Gokce, A., Özer, D., Soyman, E., Yilmaz, E., Eayrs, J. O., London, R. E., Steendam, T., Frings, C., Pastötter, B., Szaszko, B., Baess, P., Ayatollahi, S., León Montoya, G. A., Wetzel, N., Widmann, A., Cao, L., Low, X., Costa, T. L., Chelazzi, L., Monachesi, B., Kamp, S.-M., Knopf, L., Itier, R. J., Meixner, J., Jost, K., Botes, A., Braddock, C., Li, D., Nowacka, A., Quenault, M., Scanzi, D., Torrance, T., Corballis, P. M., Laera, G., Kliegel, M., Welke, D., Mushtaq, F., Pavlov, Y. G., & Liesefeld, H. R. (2025). A multilab investigation into the N2pc as an indicator of attentional selectivity: Direct replication of Eimer (1996) [Stage 2]. Acceptance of Version 3 by Peer Community in Registered Reports. https://doi.org/10.31234/osf.io/3472y_v3

2. Eimer, M. (1996). The N2pc component as an indicator of attentional selectivity. *Electroencephalography and Clinical Neurophysiology*, 99, 225-234.
[https://doi.org/10.1016/0013-4694\(96\)95711-9](https://doi.org/10.1016/0013-4694(96)95711-9)

3. Pavlov, Y. G., Adamian, N., Appelhoff, S., Arvaneh, M., Benwell, C. S. Y., Beste, C., Bland, A. R., Bradford, D. E., Bublatzky, F., Busch, N. A., Clayson, P. E., Cruse, D., Czeszumski, A., Dreber, A., Dumas, G., Ehinger, B., Ganis, G., He, X., Hinojosa, J. A., Huber-Huber, C., Inzlicht, M., Jack, B. N., Johannesson, M., Jones, R., Kalenkovich, E., Kaltwasser, L., Karimi-Rouzbahani, H., Keil, A., König, P., Kouara, L., Kulke, L., Ladouceur, C. D., Langer, N., Liesefeld, H. R., Luque, D., MacNamara, A., Mudrik, L., Muthuraman, M., Neal, L. B., Nilsonne, G., Niso, G., Ocklenburg, S., Oostenveld, R., Pernet, C. R., Pourtois, G., Ruzzoli, M., Sass, S. M., Schaefer, A., Senderecka, M., Snyder, J. S., Tamnes, C. K., Tognoli, E., van Vugt, M. K., Verona, E., Vloeberghs, R., Welke, D., Wessel, J. R., Zakharov, I., & Mushtaq, F. (2021). #EEGManyLabs: Investigating the replicability of influential EEG experiments. *Cortex*, 144, 213-229.
<https://doi.org/10.1016/j.cortex.2021.03.013>

Reviews

Evaluation round #1

DOI or URL of the preprint: https://doi.org/10.31234/osf.io/3472y_v2
Version of the preprint: 2

Authors' reply, 13 May 2025

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Decision by [Maxine Sherman](#) , posted 14 April 2025, validated 15 April 2025

Very minor revisions to "A multilab investigation into the N2pc as an indicator of attentional selectivity: Direct replication of Eimer (1996)"

Dear Dr Constant and colleagues,

Thank you for submitting your Stage 2 report and sorry for the delay in getting back to you. I've now received two reviews back from the original reviewers and I've read your manuscript as well. I agree with both of the reviewers that your Stage 2 report is extremely impressive and stays true to the Stage 1 report. The exploratory analyses are valuable additions to the manuscript as well, particularly your analysis of other N2pc time windows used in previous work - together, it's a really thorough treatment of the N2pc that'll be a very valuable contribution to the literature and I was excited to see how the results came out.

As you will see, the reviewers have some very minor suggestions. Dr Hickey made an interesting point about what the N2pc reflects. If you do address this point in the manuscript, it would be best to do so in the discussion rather than the introduction, where in-principle acceptance has already been granted.

I look forward to receiving your revised submission.

Best wishes

Maxine

Reviewed by **Reny Baykova** , 14 April 2025

Constant et al. have replicated the second EEG experiment reported in Eimer (1996), which investigated the N2pc component of the visual event-related potential (ERP). The N2pc is commonly interpreted as a marker of attention, and the original study found that it can be elicited by different stimulus properties, namely shapes and colours. In addition, Eimer (1996) also found that the amplitude of the component was greater for shapes. Constant et al. conducted a replication of the original experiment as part of the EEGManyLabs project, and a total of 22 separate labs were involved in the replication. The N2pc effect using shapes was replicated, as well as the difference in amplitude between shapes and colours. The effect using colours was not replicated using the strict replication of the original pipeline and the ICA pipeline. It was, however, replicated using the collapsed localiser pipeline and in the additional exploratory analyses which didn't use a fixed time window.

Overall, this is a very ambitious project that was conducted with great care. The study provides a valuable contribution to the literature on the N2pc and ERPs more generally. I commend the authors on the impressive amount of work they undertook with this project, and I have only a few minor comments.

1. Transparency and openness statement

I would suggest adding links to the data, analysis scripts and stage 1 report in the transparency and openness statement so that they are easier to find.

2. Tables containing Bays factors

Apologies if this is a common notation I'm not familiar with, but I found the notation "BF-0" initially confusing. I believe BF10 is the more commonly known notation, but if you prefer to go with BF-0 that's completely fine, I'd just suggest adding a note to the tables to describe what it means.

3. Figure 17

Since each dot represents the average reaction time for each lab, I would suggest adding error bars to show the variability of the data (unless it all gets too messy).

In the description of the figure, I would suggest specifying that this shows reaction times on correct trials and trials kept after rejection.

4. Figure 18

Similar to my comments for Figure 17, if it isn't too messy, it would be nice to add error bars, and describe what data was used in the figure description

5. Discussion

At the beginning of the discussion, you say that the colour manipulation is more influential because more studies use colour stimuli compared to shapes. Could you just provide some evidence to back this up?

Signed

Dr Reny Baykova

Reviewed by **Clayton Hickey**, 28 March 2025

The paper does exactly what was described in the pre-registration, plus a lot of additional exploratory analysis that is very interesting. The results are not trivial and provide new insight on a seminal paper in cognitive neuroscience.

I have some comments; all are minor.

P2 – 'Furthermore, the N2pc might reflect engagement at the location of the relevant stimulus rather...' This is a bit hard to distinguish from the preceding hypotheses and needs some clarification. That is, an account of the N2pc that posits target enhancement is an account of the N2pc as engagement at the location of the relevant stimulus, not the shift of attention proper. Similarly, an account that posits distractor suppression is an account as engagement, not the shift of attention.

The N2pc is commonly used and discussed as an 'index of the deployment of attention' or of 'attentional shifting'. This is not incorrect, but perhaps misleading... the N2pc is (mostly) an indirect index of these constructs.

It reflects the large-scale change in striate and extrastriate cortical activity that is the consequence of attention. This was a salient observation in the early papers from Luck, Eimer and others that has become somewhat lost. The first proposal of the N2pc as a reflection of a control mechanism emerged in MEG work from Max Hopf's group, where the involvement of posterior parietal cortex in generating the mN2pc was tentatively interpreted as reflecting the mechanistic implementation of attention, rather than its consequence on sensory activity.

p. 35 - '...the belief in fixed component timing is still widely held.' Needs some sort of support for the authors' impression / intuition / belief. I don't have this same impression... people have been looking at effects on component latency in visual search, and on N2pc latency specifically. There are papers cited in the MS that demonstrate that, like Brisson et al 2007. Other 'early' latency effect papers looking at search or N2pc that come to mind:

Smulders, Kok, Kenemans, Bashore (1995, Acta)

Wijers, Mulder & Mulder (1997, Psychopys)

Robitaille & Jolicoeur, (2006, Neuroreport)

Kiesel, Miller, Jolicoeur, & Brisson (2008, Psychophys)

Hickey, van Zoest, & Theeuwes (2010, EBR)

More broadly, there were reports of P3 latency effects from Donchin and Kok in the '80s, probably the '70s too. I remember very early work from Falkenstein in the '90s with latency effects on Ne/ERN, either in the initial report or soon after. It could be more justifiable to say that the shift in N2pc timing observed here is larger than was expected across by the large group of authors contributing to this paper.

Spelling etc:

p. 8 - 'This copy was high-pass filtered at 2 Hz (passband edge)...' for completeness, it would be good to have the same level of detail as for other filter descriptions.

p. 9 - '...that is, ERP amplitude at electrodes P07/9 are lower...' to '...are more negative...'

p. 36 - The brightness of monitors has broadly increased over the last 40 years, and this could have something to do with the difference between the original report and these replications. CRT monitors were pretty dim by default, and and if you increased brightness the monitors degraded and became dimmer over time. If it was an early LED panel - unlikely as no one used them for vision research - then it's even more probable, as the original fluorescent backlights were awful.

signed, Clayton Hickey