Scanning the Neural Correlates of Consciousness

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INTRODUCTION

A central role of fMRI in the quest for the Neural Correlates of Consciousness

- In the last decades, consciousness research has been focused on investigating brain activity associated with conscious processing, or neural correlates of consciousness (NCC)[1]. A common approach to investigate NCC is to test the scope of unconscious processing[2].
- In this quest, fMRI has been and continues to be one of the privileged neuroimaging methods[3].

A fundamental statistical fallacy in consciousness science

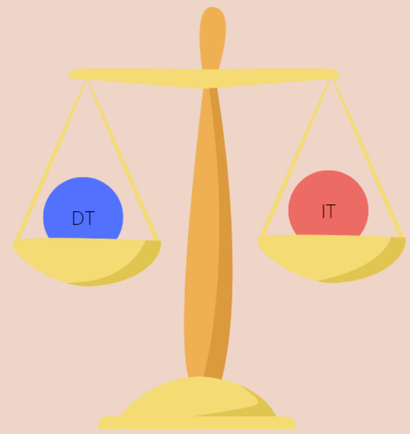
- To rule out awareness, researchers usually perform two measures:
  a. a measure of stimulus awareness, or Direct Task (DT), e.g., visibility rating or two alternative forced-choice task .
  b. a measure of stimulus processing , or Indirect Task (IT), e.g., reaction time or brain activity[4].
- If subjects perform at chance at discriminating the stimulus (DT) while the measure of processing (IT) is above chance, researchers conclude that the stimulus is processed unconsciously.
- This standard reasoning is fundamentally flawed for statistical reasons, as the sensitivities of the two measures are not properly compared, creating the misleading impression of a difference in sensitivities even if there is none[5].

THE SENSITIVITY METHOD

- The sensitivity method consists in estimating a d' value from published summary statistics given minimal assumptions. The sensitivities of the two tasks can then be compared on the same scale to determine if there is an Indirect Task Advantage (ITA), i.e., if the sensitivity of the IT is significantly superior to the sensitivity of the DT.
- The sensitivity of brain data (IT) is estimated either from decoding accuracies or BOLD signal variations using the following formula (scan the QR code for more details):

$$d'_{indirect} = t \cdot c_{N,K,q^2}$$

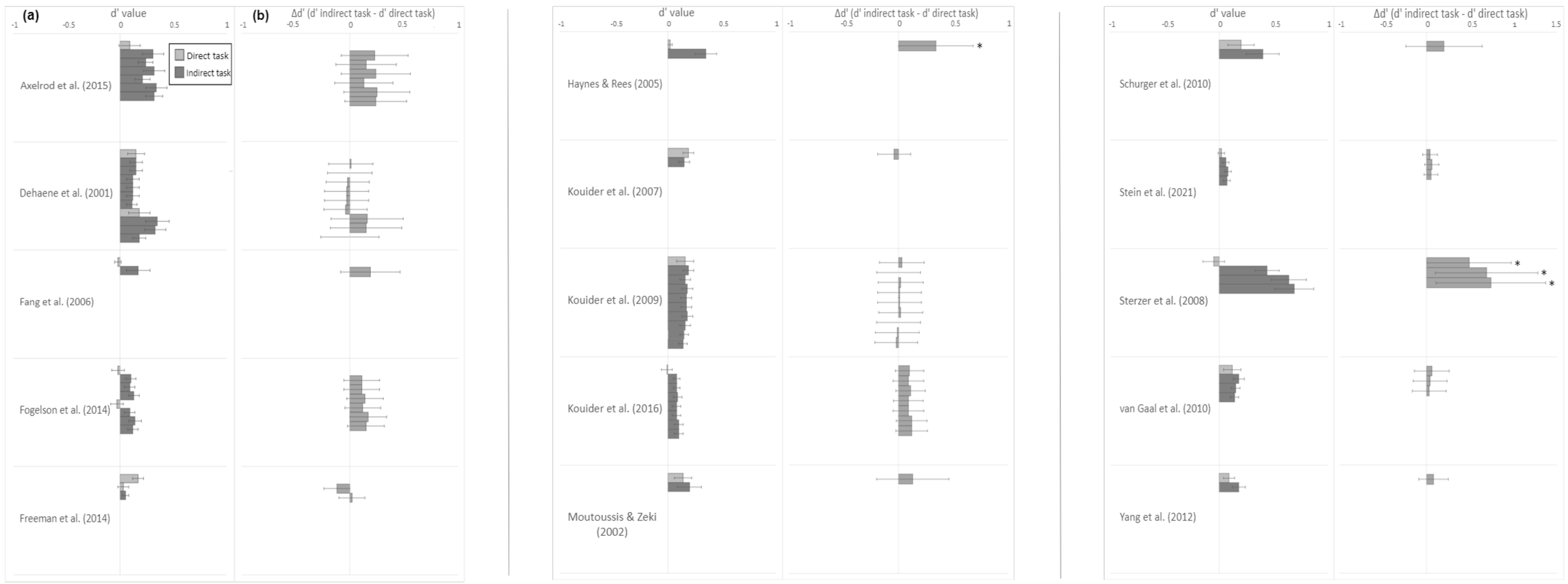
- q^2 corresponds to the estimation of the standard deviation of true sensitivities across subjects. It was here estimated for fMRI studies using data from Stein et al. (2021)[6].
- We then compare the two sensitivities and compute the 95% confidence interval to determine if there is enough evidence for an ITA.



Note. Sensitivity measures of the direct and indirect tasks are directly compared on the same scale (d') to determine if the indirect task is more sensitive to stimulus information.

RESULTS

When directly comparing the sensitivity of the brain data with the sensitivity of the behavioral data, four of the 53 comparisons we performed still supported the existence of a ITA. This represents two of the 15 studies we reanalyzed that still provided some evidence for an ITA after a direct comparison of sensitivity was performed. These results were obtained using a benefit-of-the-doubt approach which favors conservative findings (i.e., ITA).



Note. (a) Sensitivity values for the direct and indirect tasks. SE are indicated with error bars. (b) Sensitivity difference between the two tasks. 95% confidence intervals are indicated with error bars. ITAs are indicated with asterisks.

DISCUSSION AND NEXT STEPS

Implications for the field of consciousness science and the quest for the NCC

- A large proportion of the fMRI consciousness studies we reanalyzed fail in finding evidence for unconscious processing when directly comparing the sensitivities of the two tasks.
- These results question the validity of previous conclusions regarding the extent of unconscious processing, which might have been overestimated. Ultimately, they might have an impact on our current conception of the NCC and our understanding of consciousness.

We recommend consciousness researchers to directly compare behavioral and brain data using the sensitivity method

- We propose a straightforward method to compare the two measures on the same scale and determine if the sensitivity of the unconscious processing measure indeed outperforms conscious performance.
- This method has many side benefits for the field by making clear that the two tasks' procedure should be as similar as possible (e.g., same number of participants and trials, similar task and experimental design), thus avoiding biases towards finding evidence for unconscious processing.

REFERENCES

[1] Crick, F. & Koch, C. (1990). Saunders Scientific Publications
[2] Rees, G., Kreiman, G. & Koch, C. (2002). *Nat. Rev. Neurosci.*
[3] Hesselmann, G. (2013). *The Neuroscientist*
[4] Hannula, D. E., Simons, D. J. & Cohen, N. J. (2005). *Nat. Rev. Neurosci.*
[5] Meyen, S., Zerweck, I. A., Amado, C., von Luxburg, U., & Franz, V. H. (2022). *J. Exp. Psychol.: Gen.*
[6] Stein, T., Kaiser, D., Fahrenfort, J. J. & Van Gaal, S. (2021). *PLoS Biol.*

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Scan QR code for more information: full references, results values, and more!

SCAN ME

https://github.com/JoaquimStr/sensitivity-method