Aix Marseille université cnrs

Laboratoire de Psychologie Cognitive

The Active Pupil

Pupil size in attention and active vision

Sebastiaan Mathôt

http://www.cogsci.nl/smathot

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013) under REA grant agreement n° 622738.

The pupillary light response

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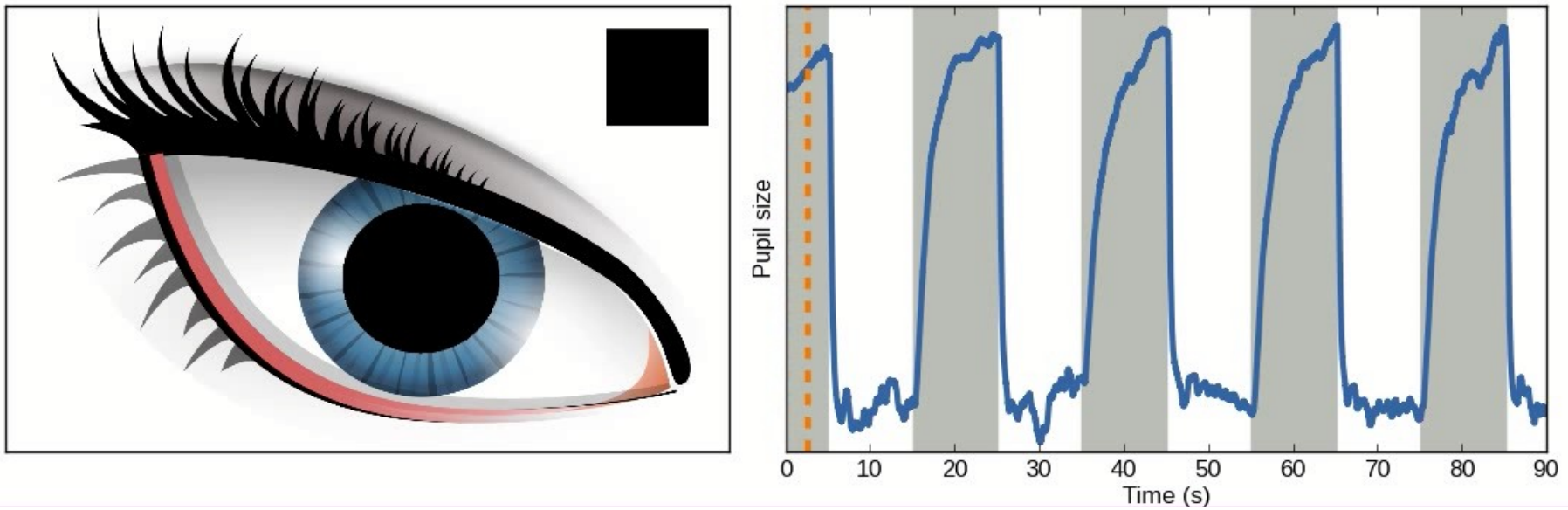

Henceforth *PLR* (pupillary light response)

The pupillary light response

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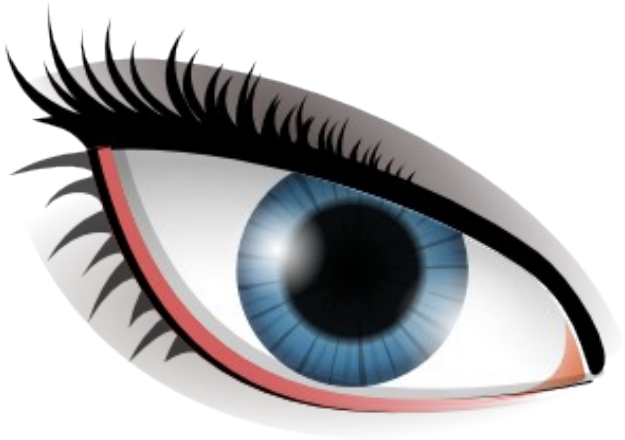
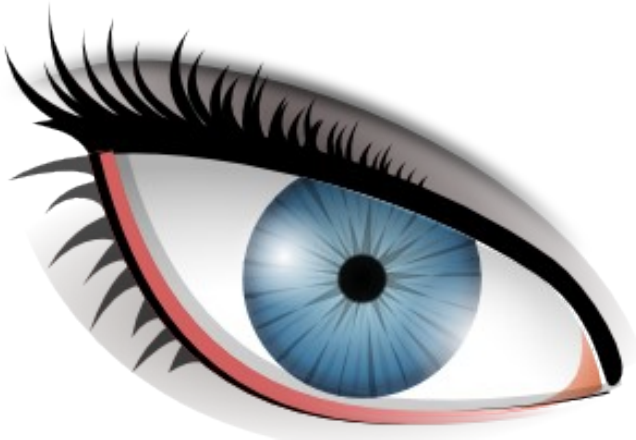


Captures lots of light

Has lots of optical distortions



Captures less light

Has less optical distortions

The active pupil

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- The PLR is traditionally considered a reflex
- Recent studies show cognitive influences
  - Brightness illusions and pictures of the sun (Laeng et al., 2012; Naber et al., 2013; Binda et al., 2013)
  - Binocular rivalry (Naber et al., 2011; Fahle et al., 2013; Harms, 1937)
  - Mental imagery (Laeng & Sulutvedt, 2014)
  - Shifts of attention (Binda et al., 2013; Mathôt et al., 2013, 2014; Naber et al., 2013)

Talk outline

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- The pupillary light response as a measure of
  - endogenous (voluntary) attention
  - exogenous (reflexive) attention and inhibition of return
  - eye-movement preparation
- Pupillometry and human-computer interaction
  - Decoding attention
- Important:
  - Visual spatial attention ≠ mental effort
  - The pupillary light response ≠ effort-related dilation

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Does your pupil constrict when you covertly attend to something bright?

Mathôt, van der Linden, Grainger, & Vitu (2013) doi:10.1371/journal.pone.0078168

Paradigm

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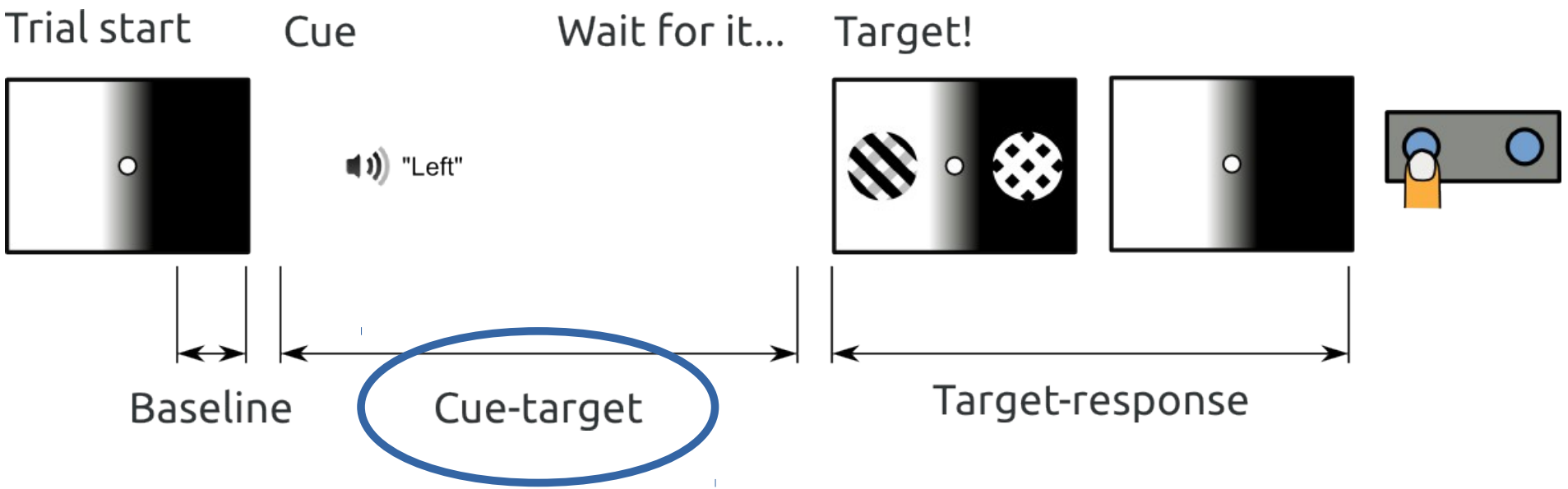

Predictions

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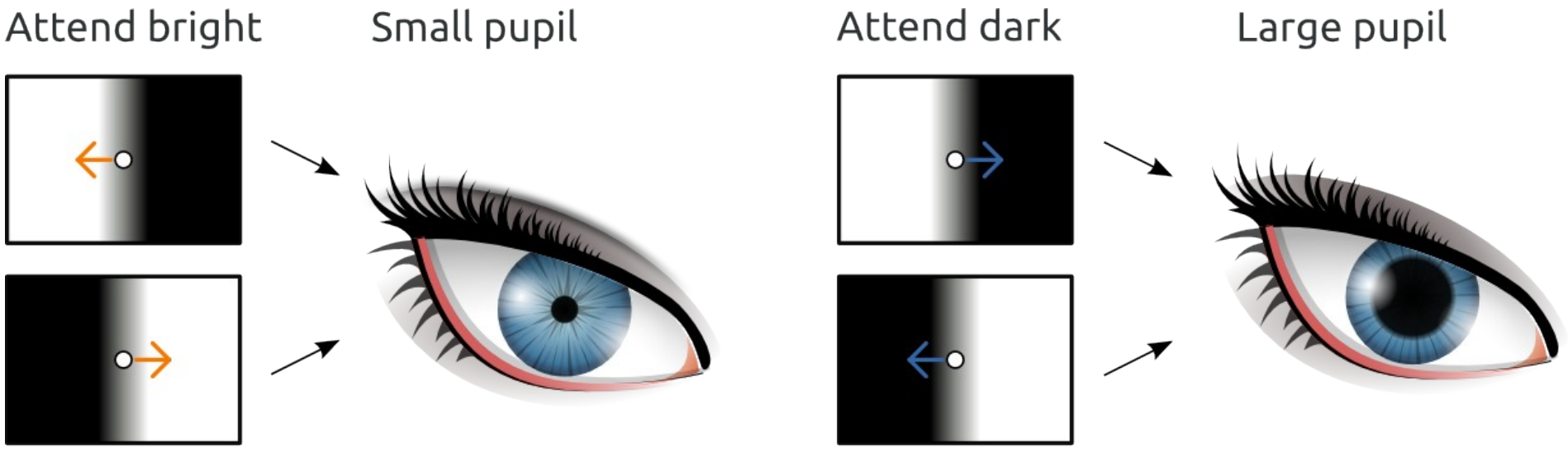

Results

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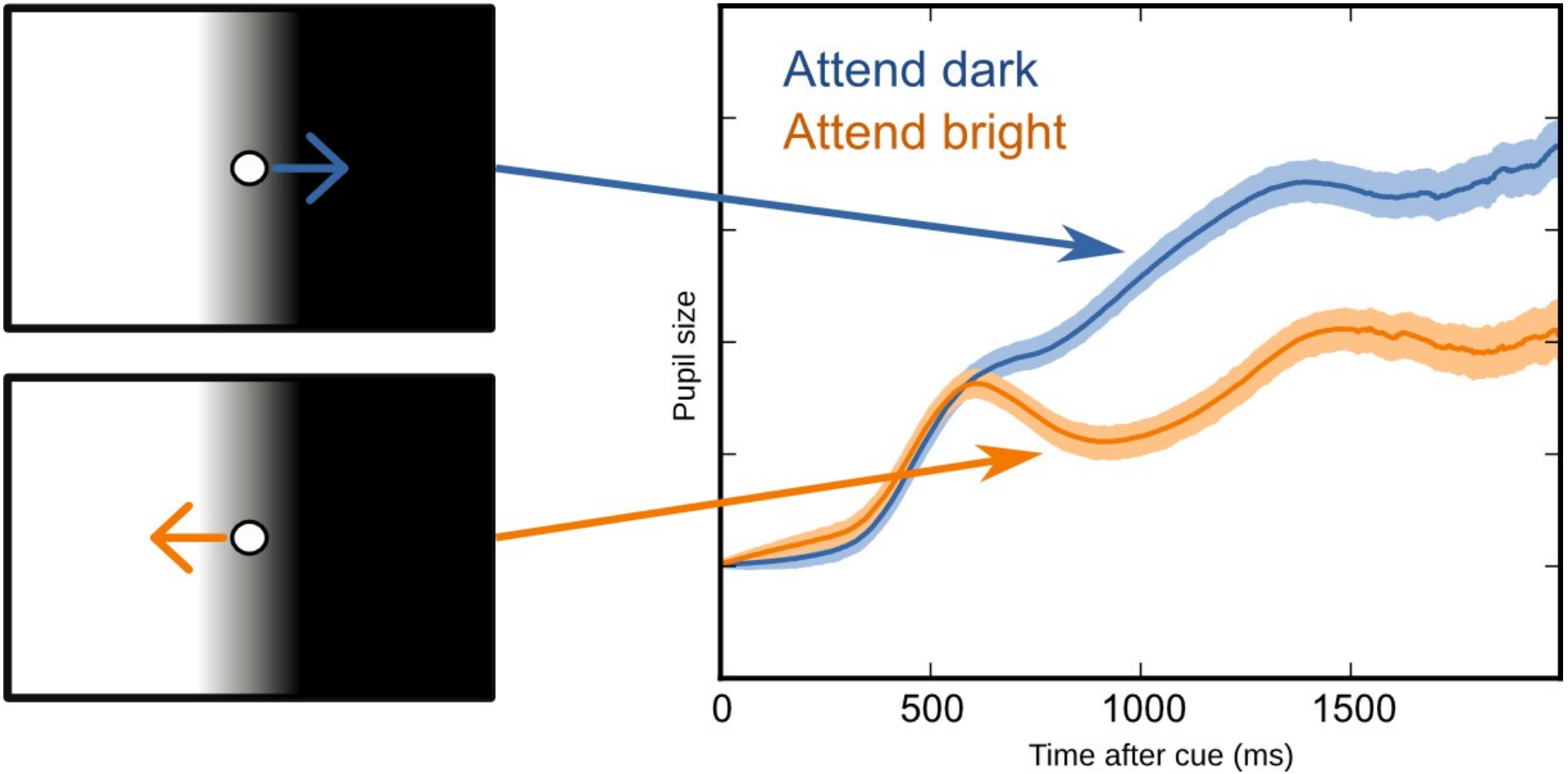

Discussion

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- Pupil size reflects the focus of attention
  - Attend to bright → Small pupil
  - Attend to dark → Large pupil

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Does your pupil reveal exogenous orienting and inhibition of return?

Mathôt, Dalmaijer, Grainger, & Van der Stigchel (2014) doi:10.1167/14.14.7

Methods

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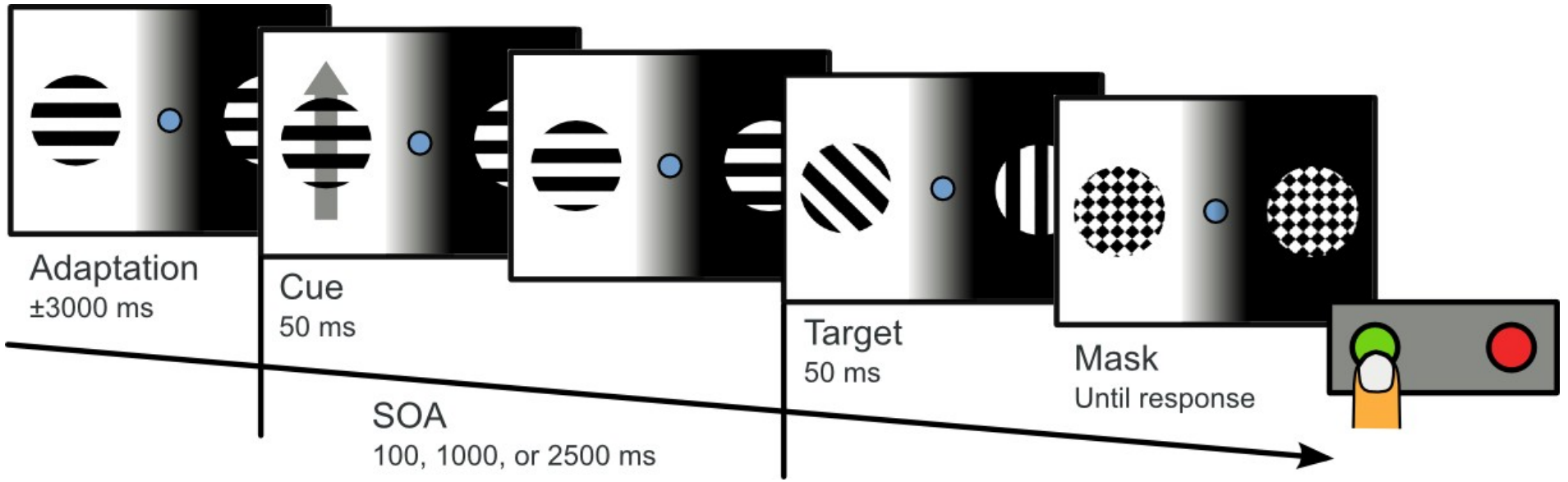

Results

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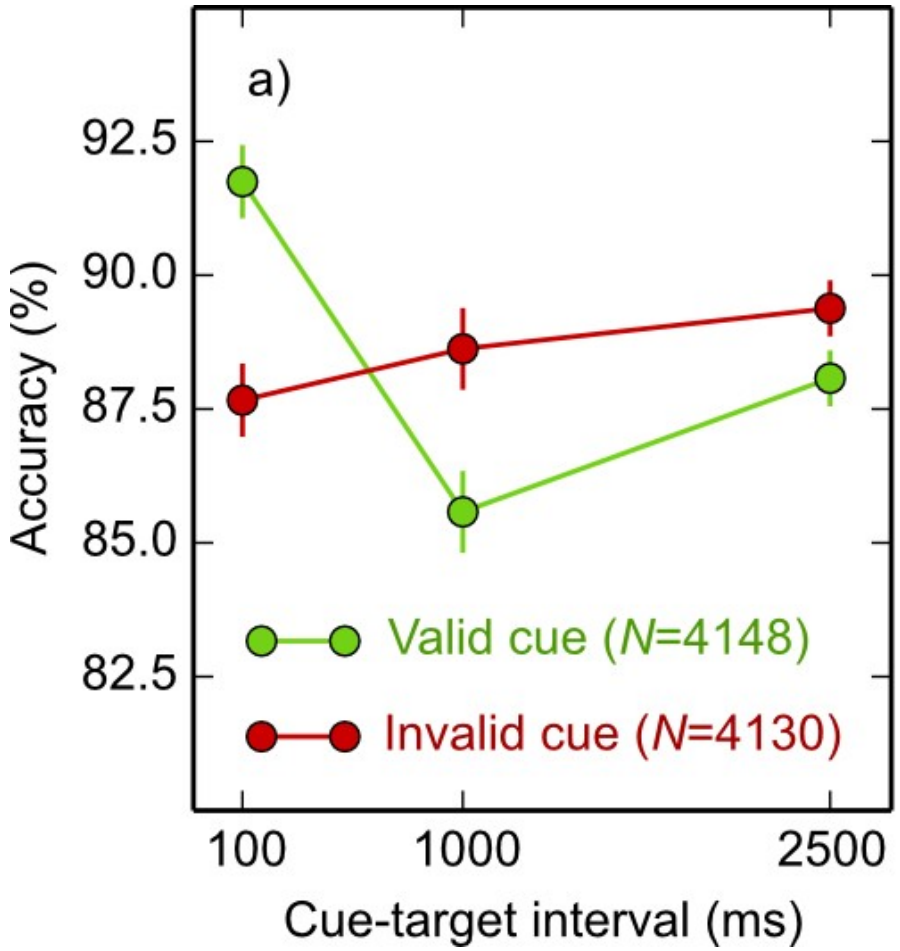

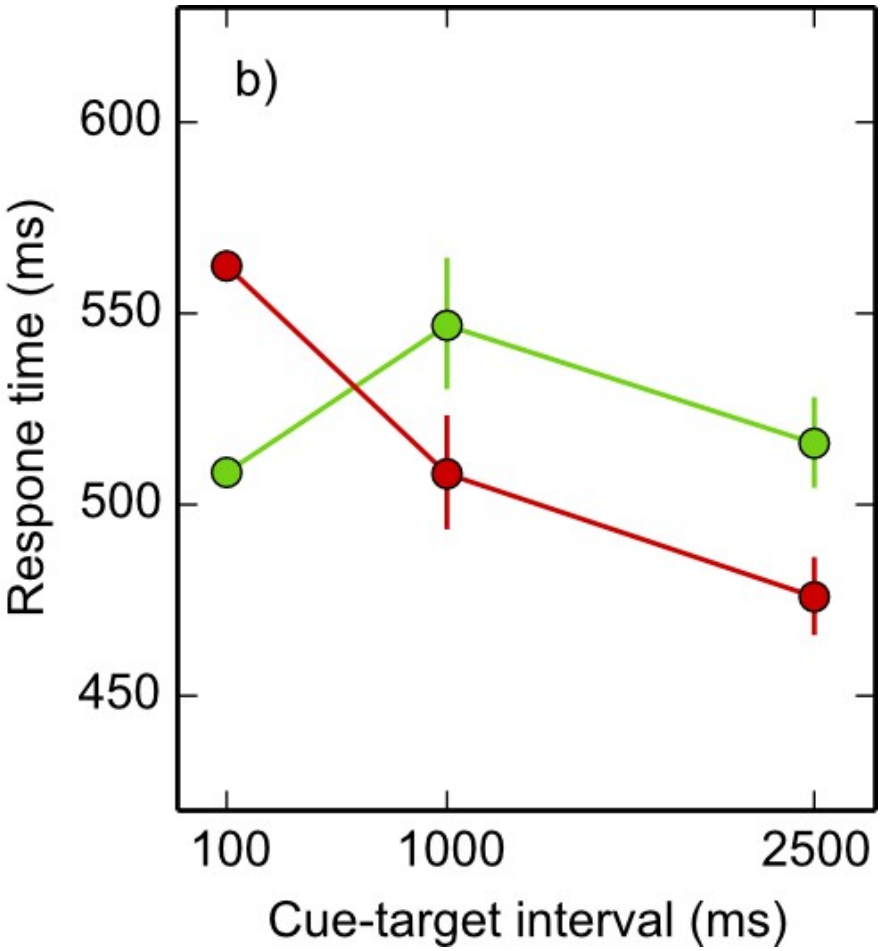

Prediction

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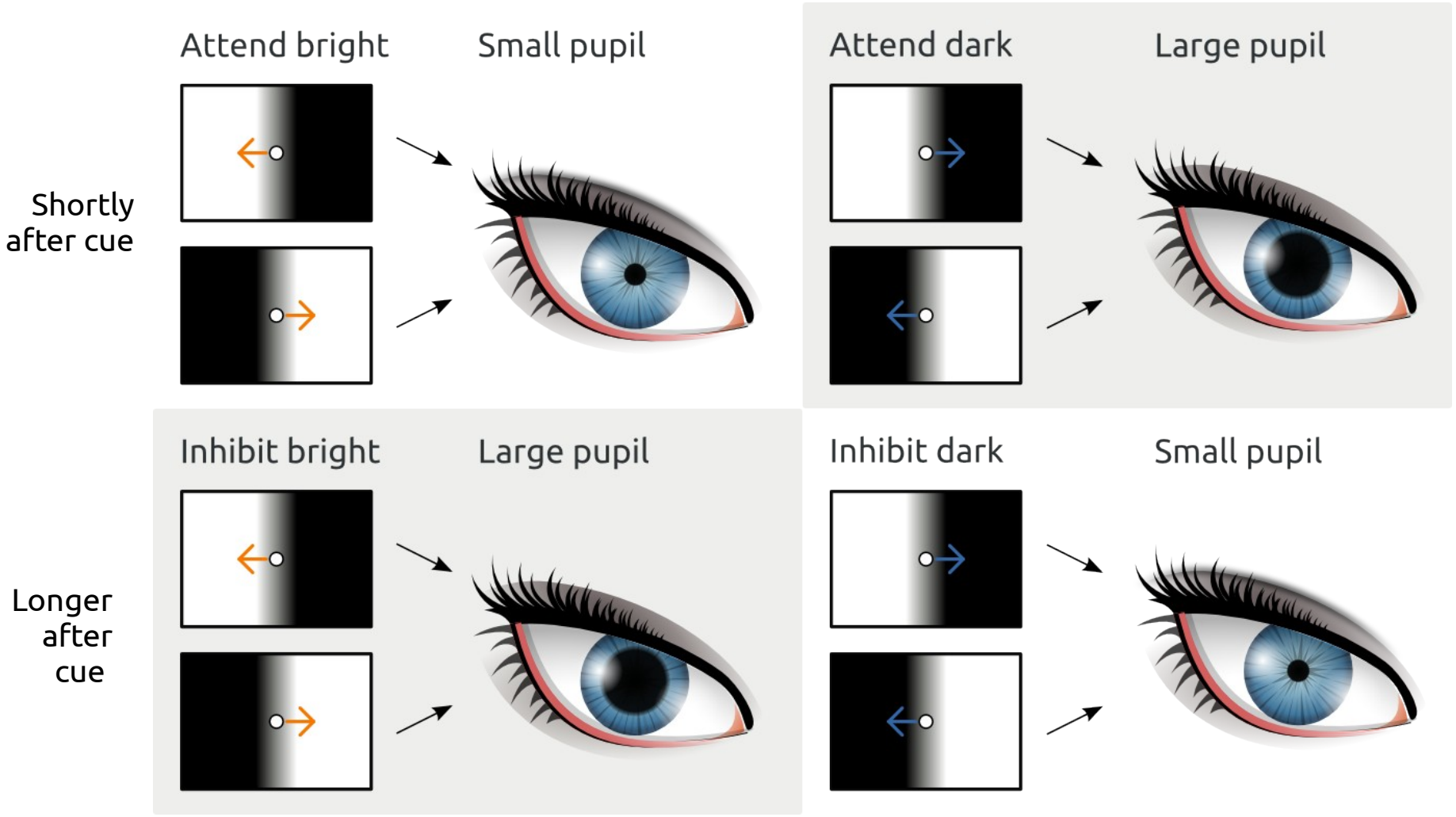

Results

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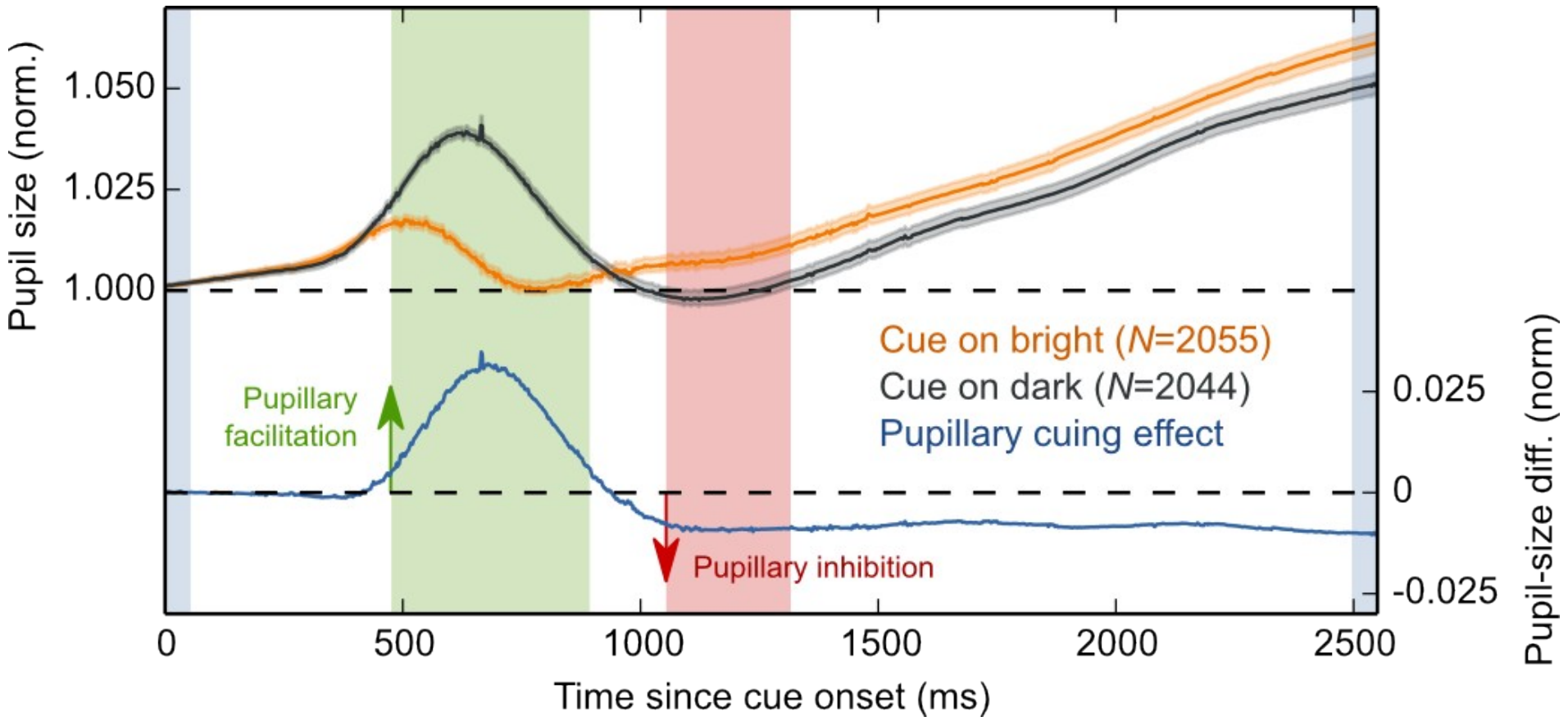

Interim discussion

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- Pupil size reflects exogenous orienting
- … and subsequent inhibition of return
- Can we link this to behavior?
  - Strong inhibition of return → Strong inhibition of light response?

Results

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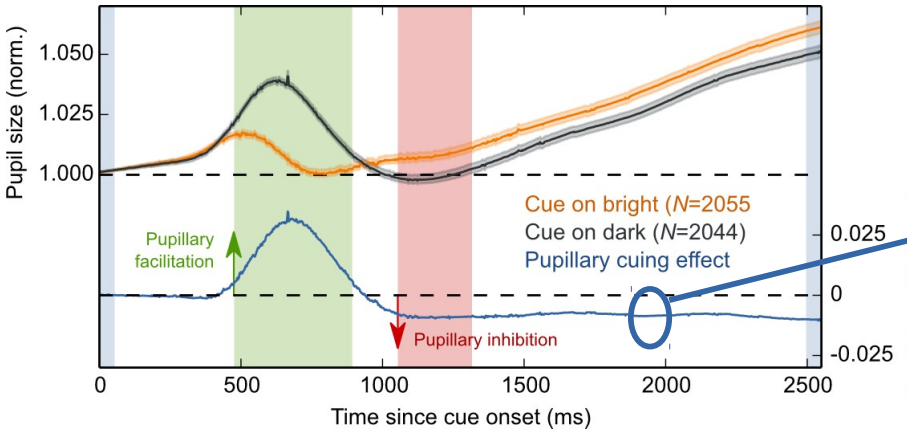

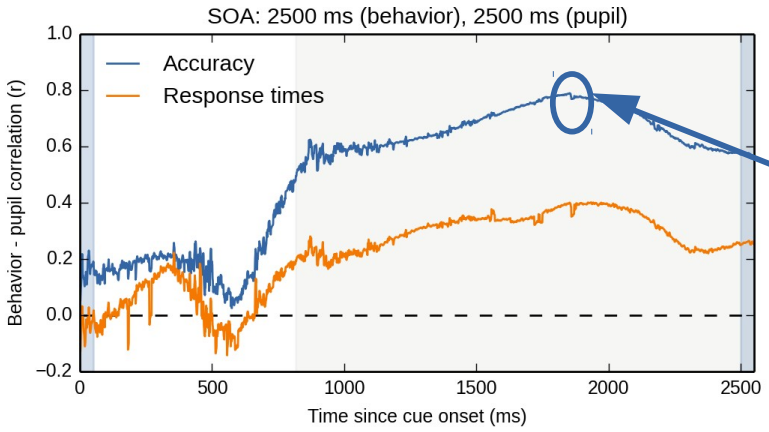

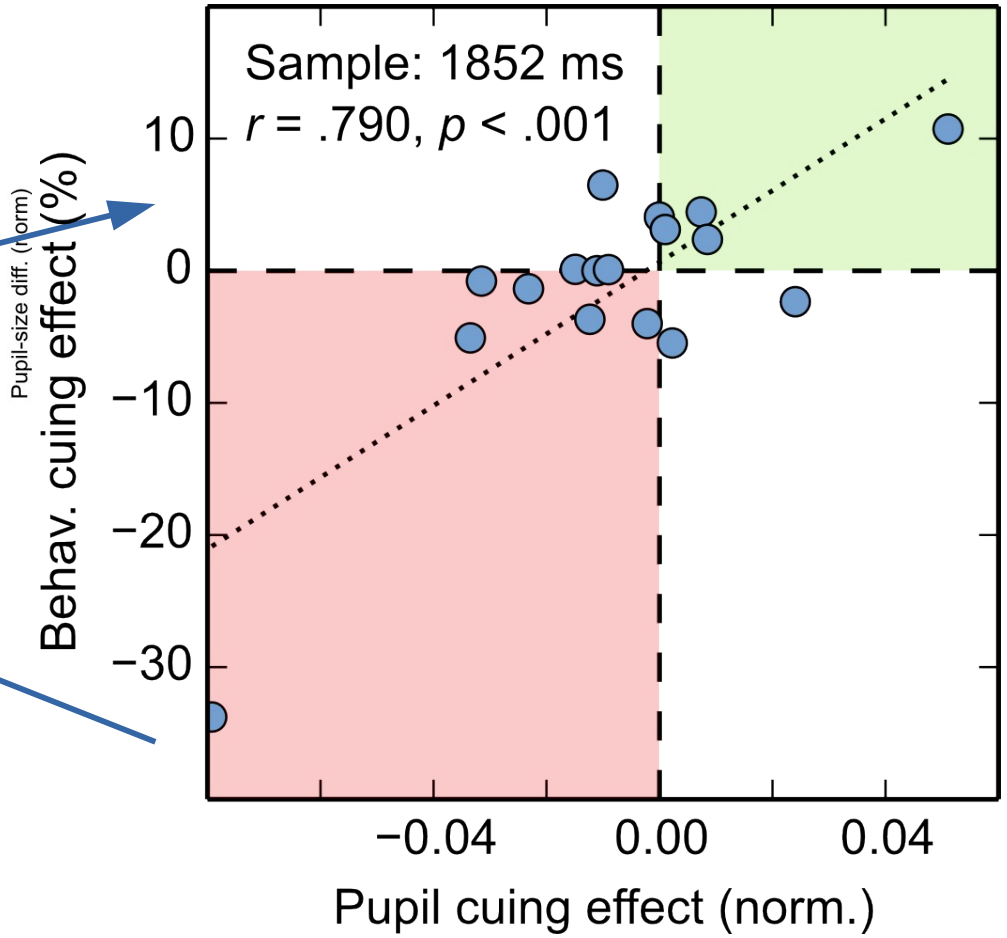

Results

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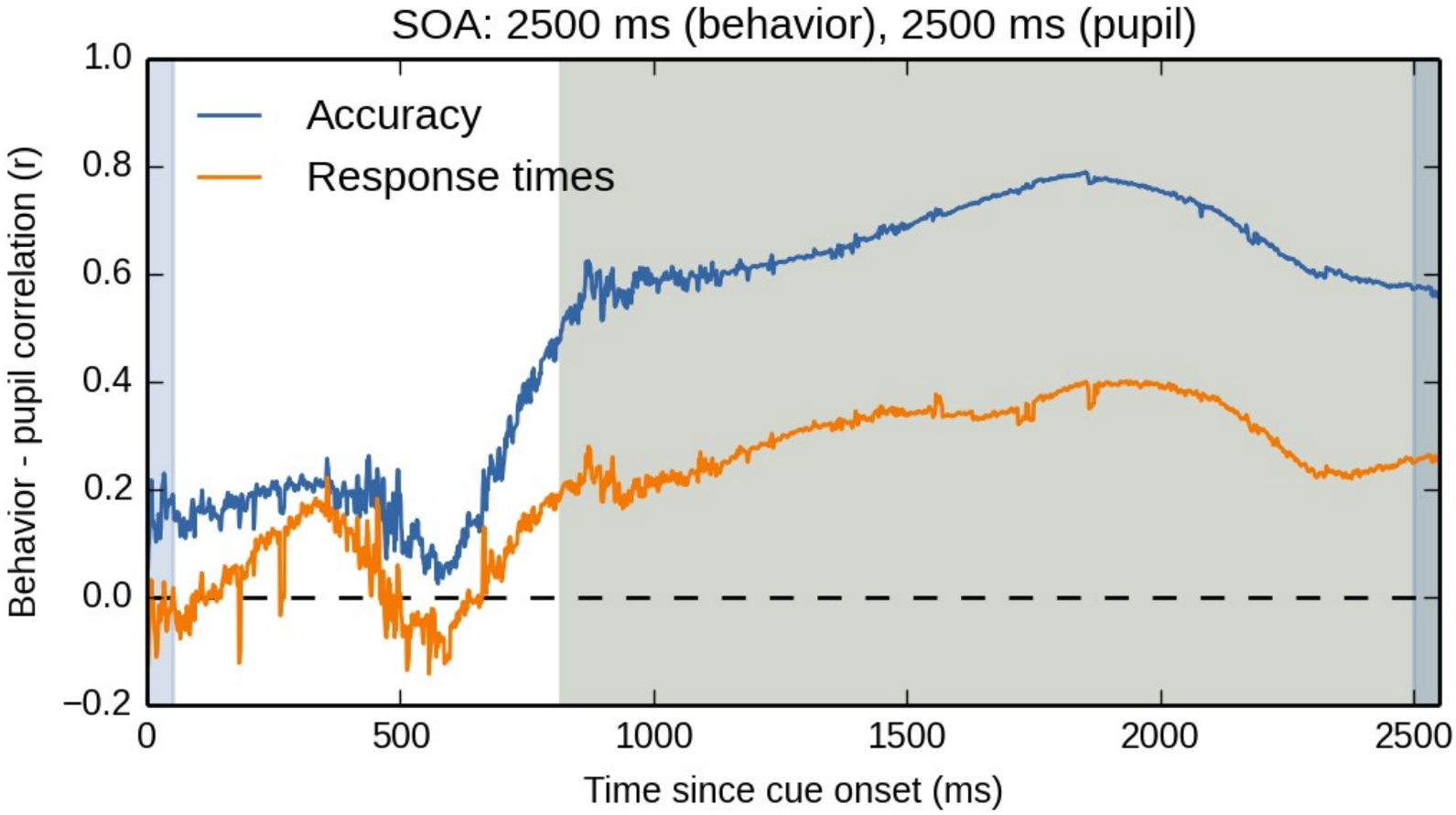

Discussion

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- The strength of the inhibitory pupil effect is related to the strength of inhibition of return
- … analogous to what we found before for endogenous orienting (Mathôt et al. 2013)

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Does your pupil constrict already before an eye movement towards a bright stimulus?

Mathôt, van der Linden, Grainger, Vitu (2015) doi:10.1037/a0038653

Paradigm

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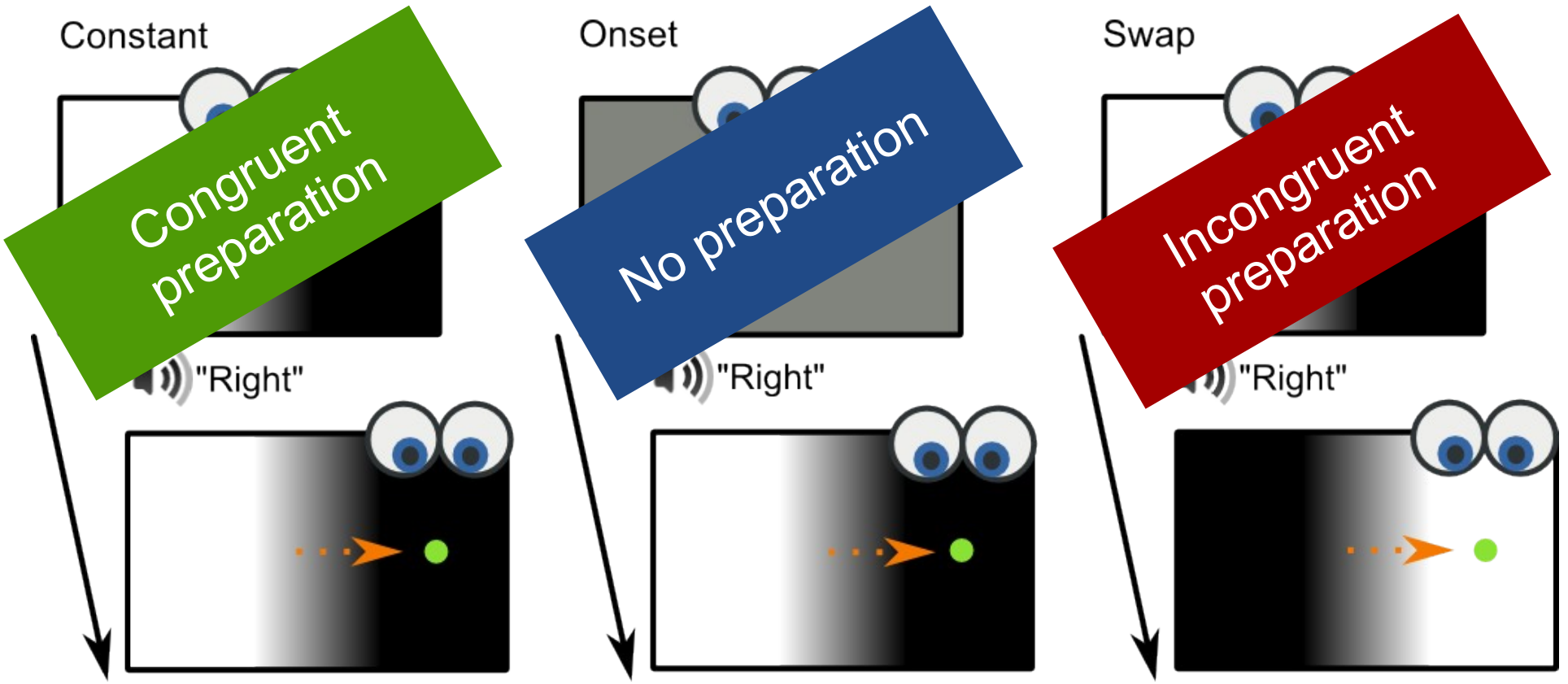

Predictions

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- Reduced light-response latency
  - If preparation is possible …
    - the Constant condition
  - … relative to when it is not
    - the Onset condition
- Initially (seemingly) inverse light response
  - If preparation is incongruent
    - the Swap condition

Results

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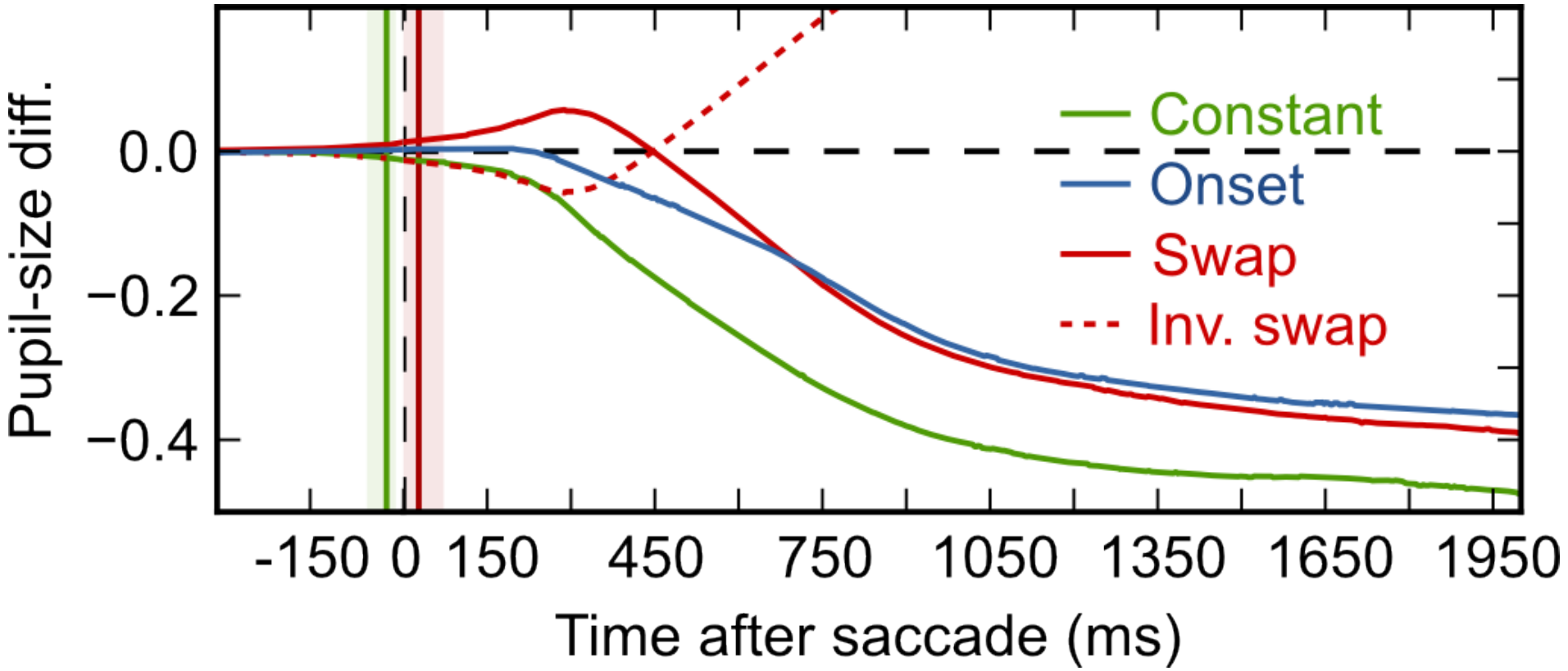

Interim discussion

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- We find that a pupillary light response is initiated during eye-movement preparation
- But how long before the eye movement does this start?

Modeling

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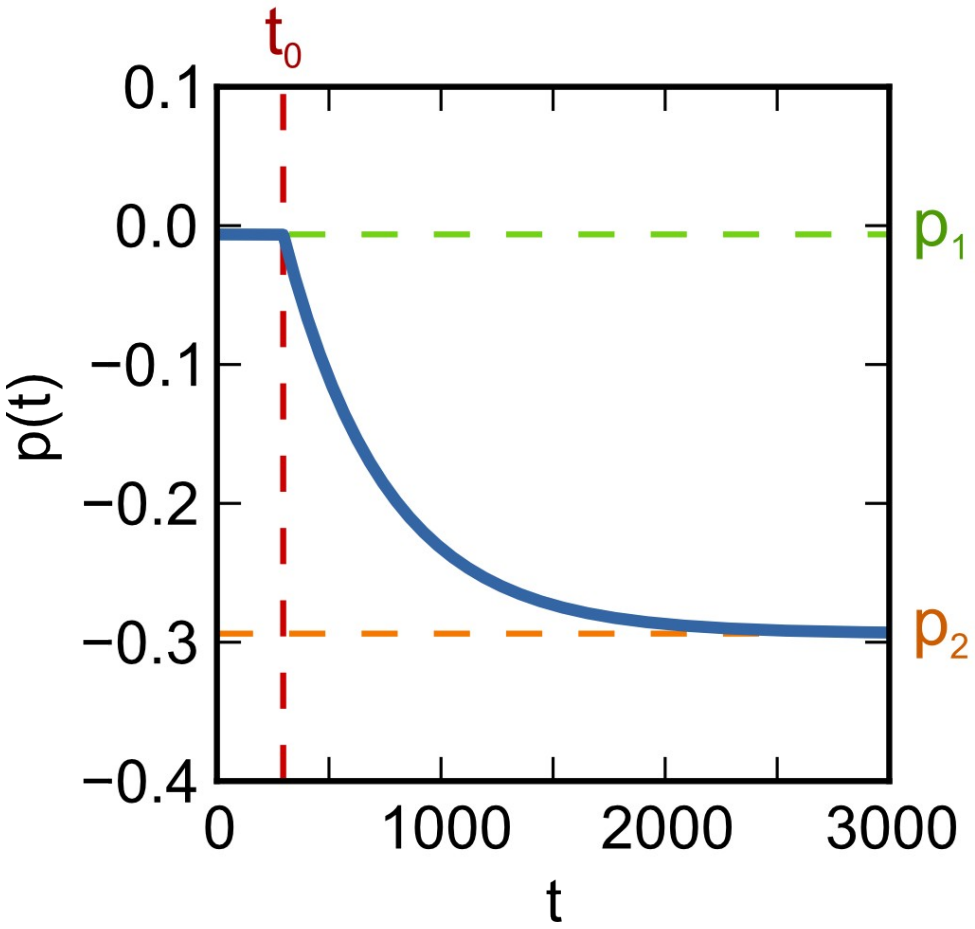

Modeling results

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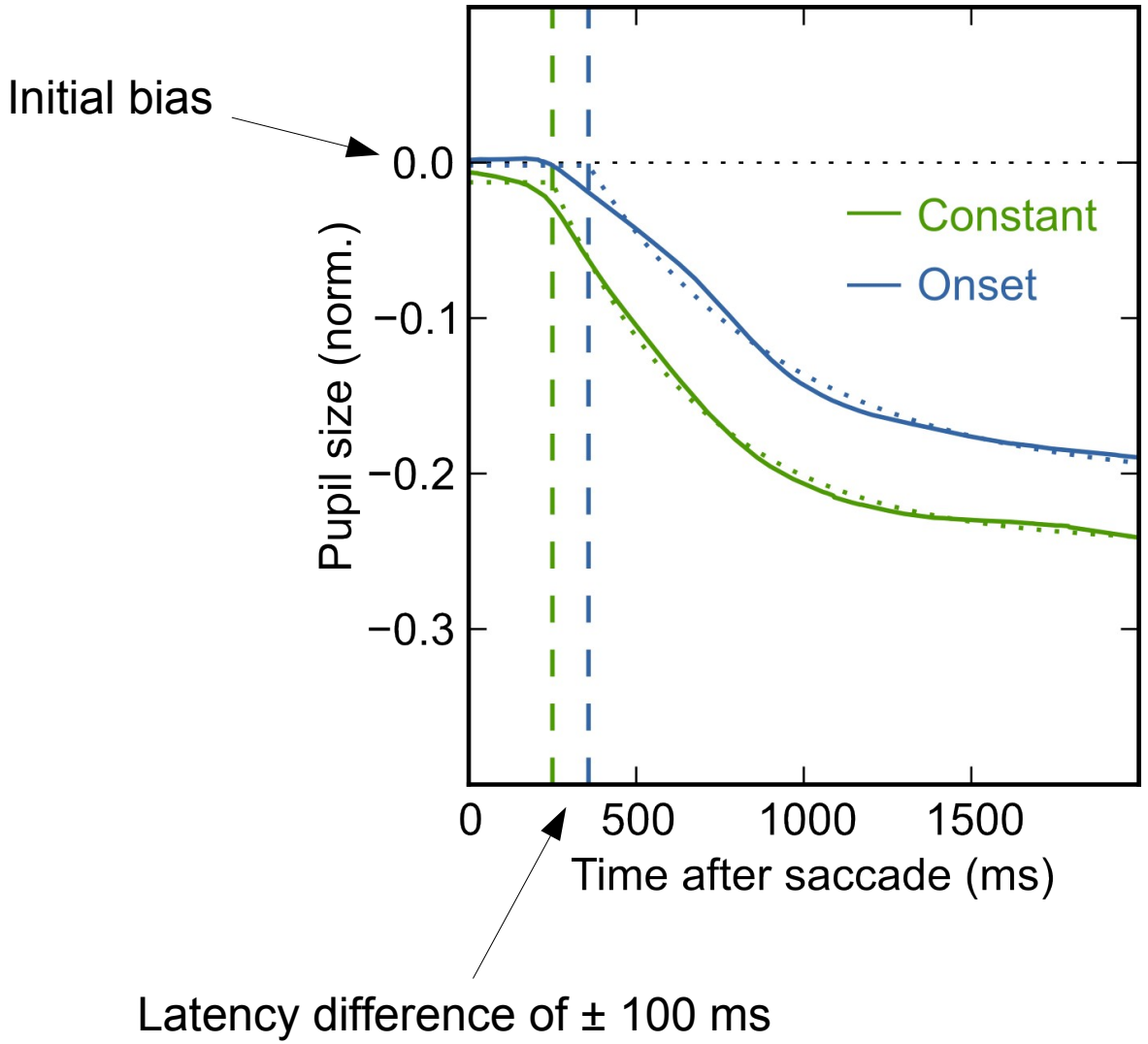

Discussion

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- A pupillary light response is initiated during eye-movement preparation …
- About 100 ms before the eye movement
- This matches the time-course of the pre-saccadic shift of attention (Rolfs & Carrasco, 2012; Deubel, 2008)

Discussion

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The pupil adjusts its size during eye-movement preparation as soon as attention shifts to the target of an upcoming eye movement

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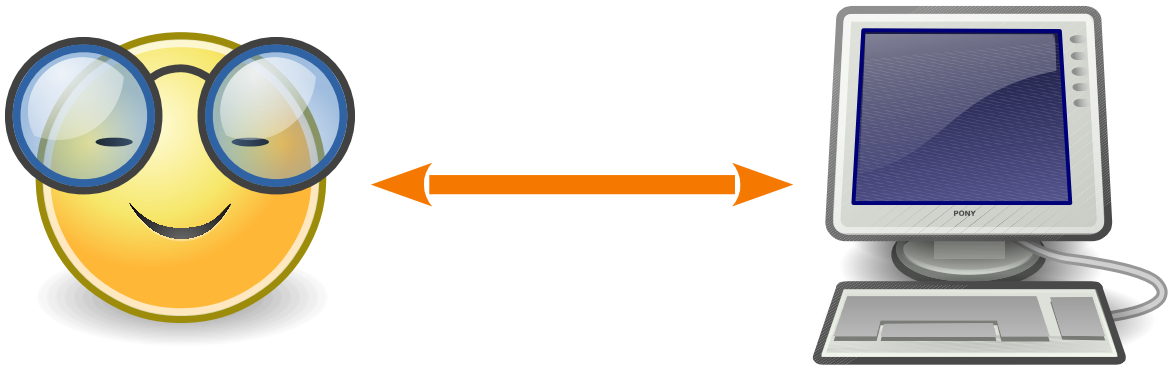
Can you build a 'pupil-computer interface' (PCI)?



With JB Melmi, Lotje van der Linden, and Stefan van der Stigchel

PCI

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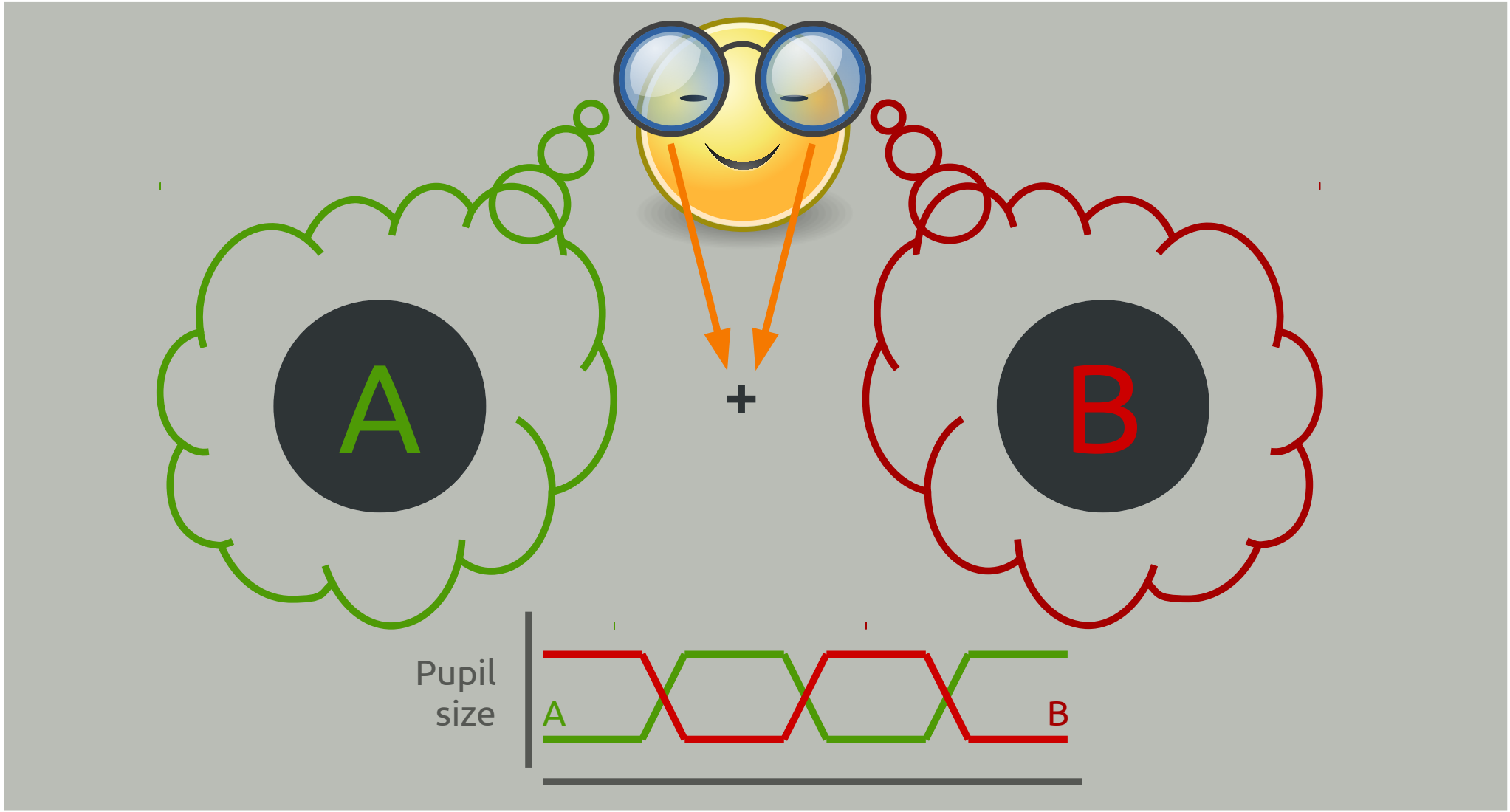

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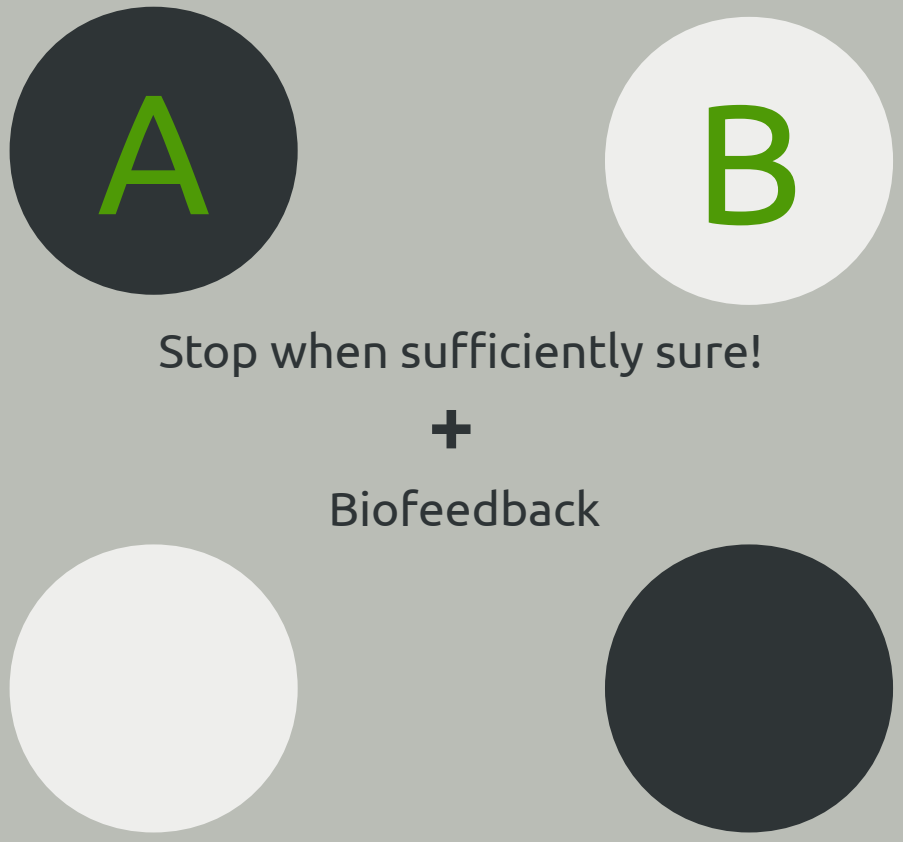

Stop when sufficiently sure!

+

Biofeedback

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Does it work?

Results

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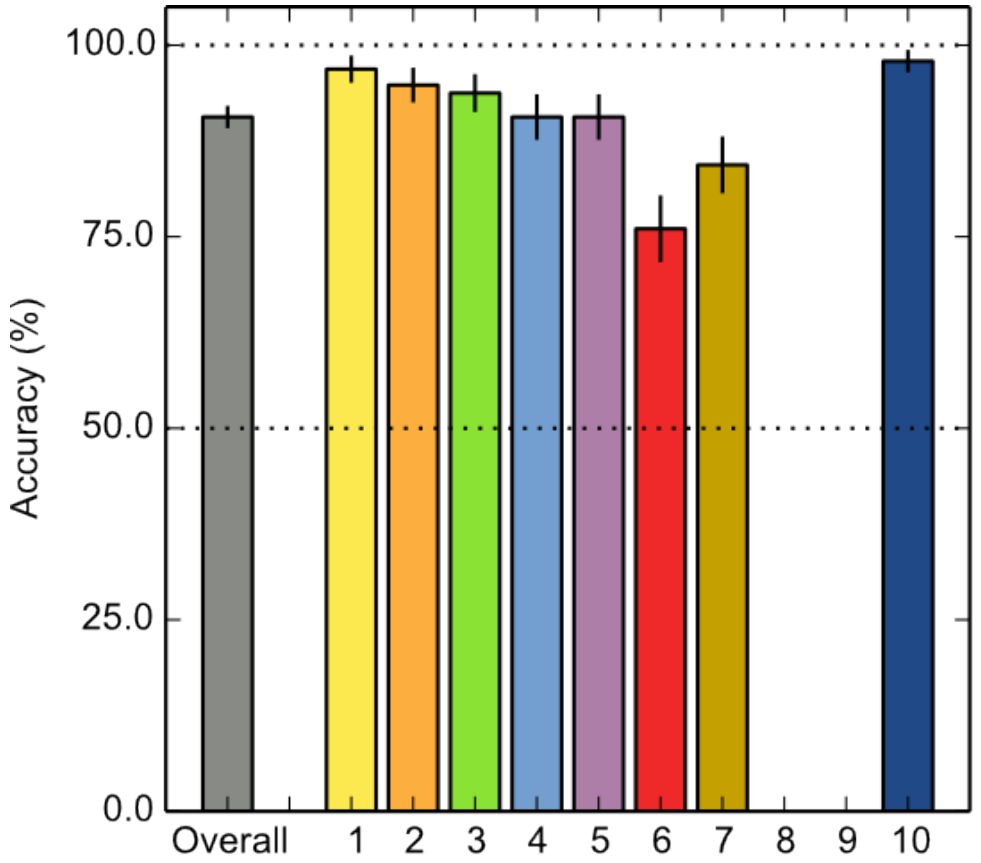

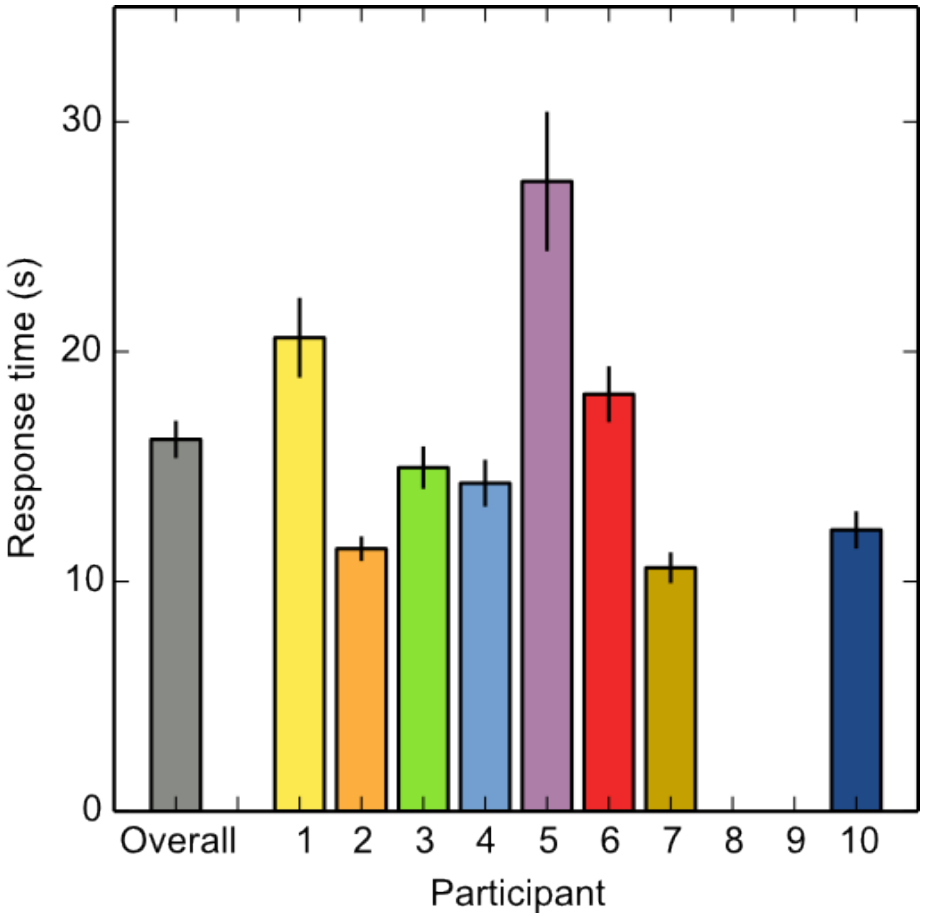

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Applications?

Applications

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- Communication device
  - Patient groups
    - Muscular diseases, locked-in syndrome
  - Covert password input
- Training
  - Train sustained attention
- Assessment
  - Assessing sustained attention

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Conclusion

Conclusion

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- The pupillary light response is not a passive reflex to light …
- … but is a type of eye movement that reflects attention and eye-movement preparation
- … and is useful for human-computer interaction
- To understand active vision, you therefore need to understand …

Conclusion

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The Active Pupil

Thank you for your attention

Sebastiaan Mathôt

Slides for this talk (and much more) are available from http://www.cogsci.nl/smathot

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