The interpretation of psychometric functions

Miguel Ángel García Pérez
Rocío Alcalá Quintana

Departamento de Metodología
Universidad Complutense, Madrid

miguel@psi.ucm.es

The interpretation of psychometric functions

Psychophysical tasks were designed to study perceptual processes in
– classical senses (vision, audition, haptics, ...)
– non-classical senses (proprioception, nociception, balance, ...)
– the absence of sense organs and physical sources: time perception

They are also used as a probe in the study of other processes:
– attention
– emotional states

And also in applied research for, e.g., comparative analyses of
– the perceived quality of compressed images
– the perceived quality of color rendition

All of these uses require that the data collected are unequivocally interpretable as reflecting pure influences of the processes under investigation, without contaminating influences from other factors

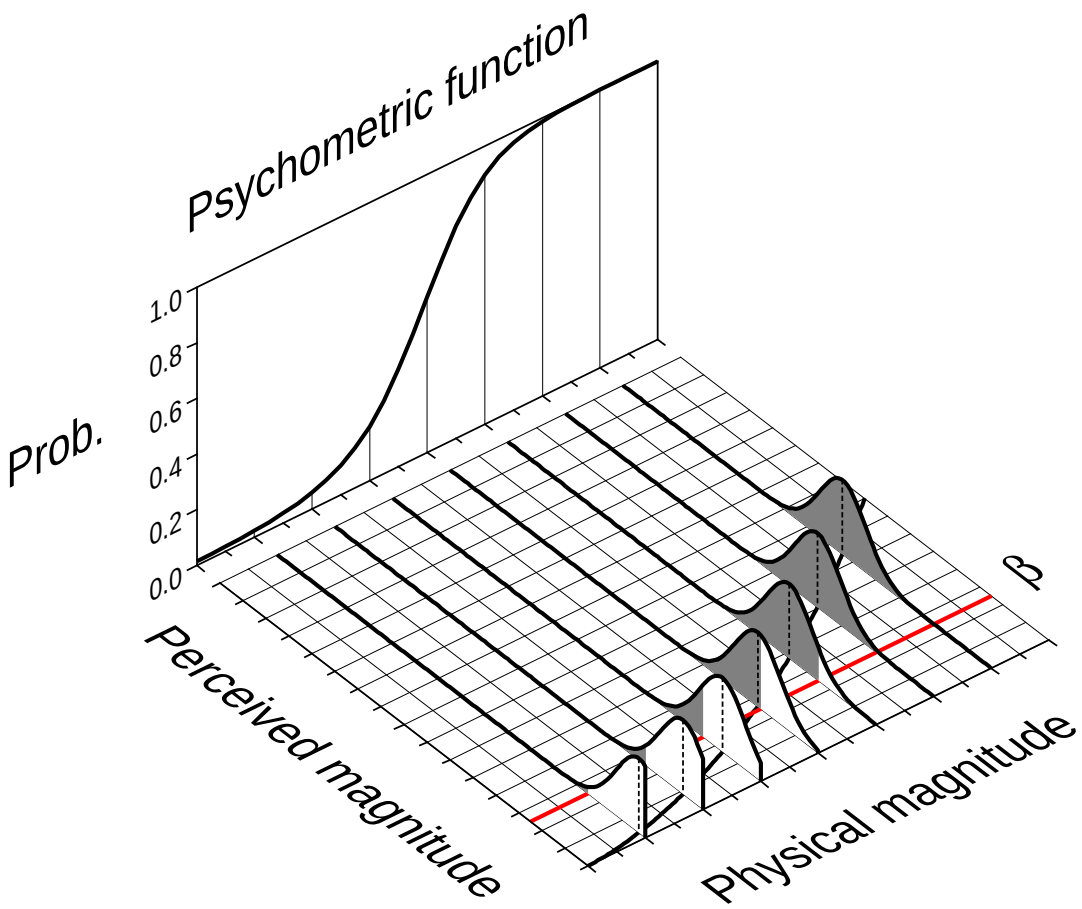
Is this the case?

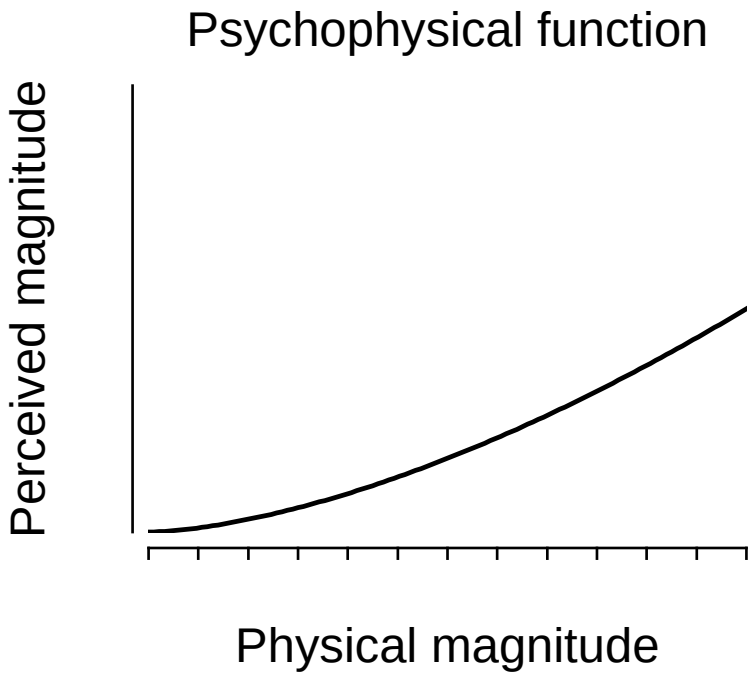
Plan of the talk

1. Link between the psychophysical function and the psychometric function
2. Two major types of psychophysical task, and how they are supposed to produce psychometric functions
3. Empirical evidence indicating that something is not quite right in the assumptions
4. A more fitting set of assumptions (just one replaced)
5. Some empirical examples
6. Why some widespread practices should never have been used
7. Recommendations for good practice

Two aspects of psychophysical performance

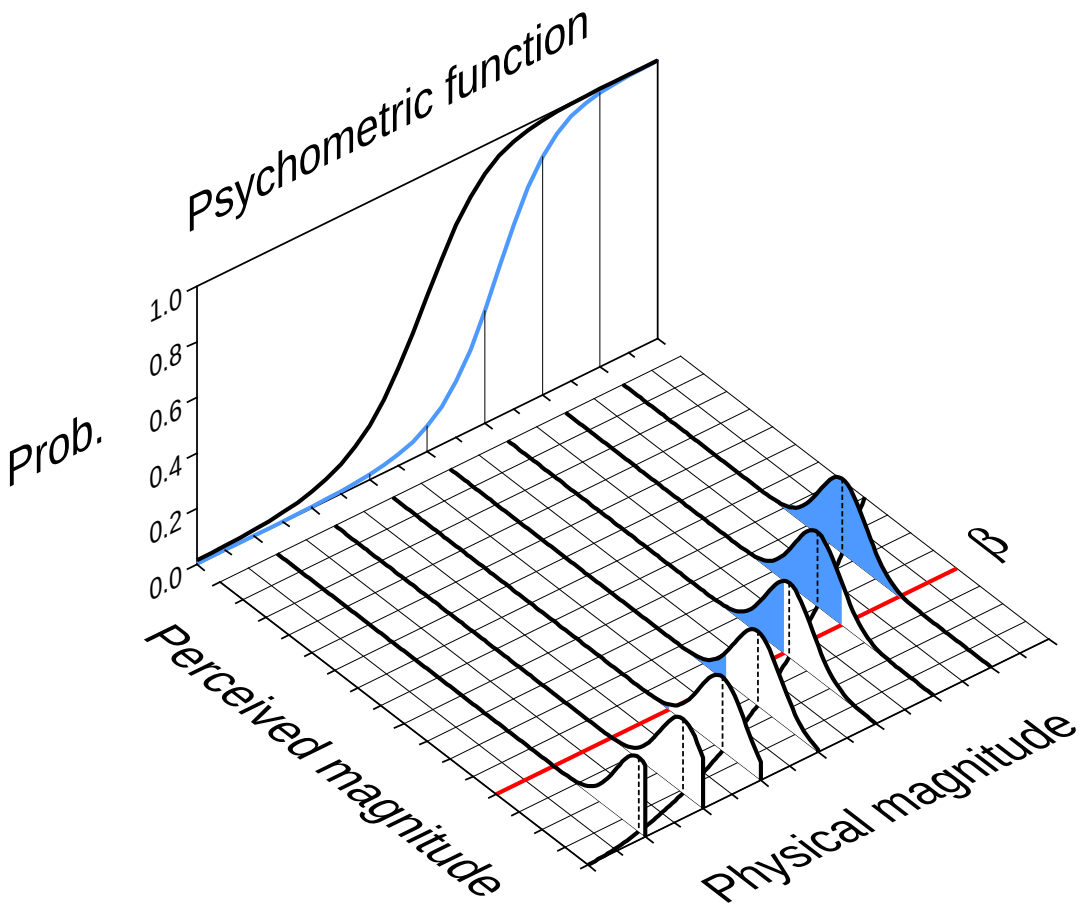
Relation between physical and perceived magnitude

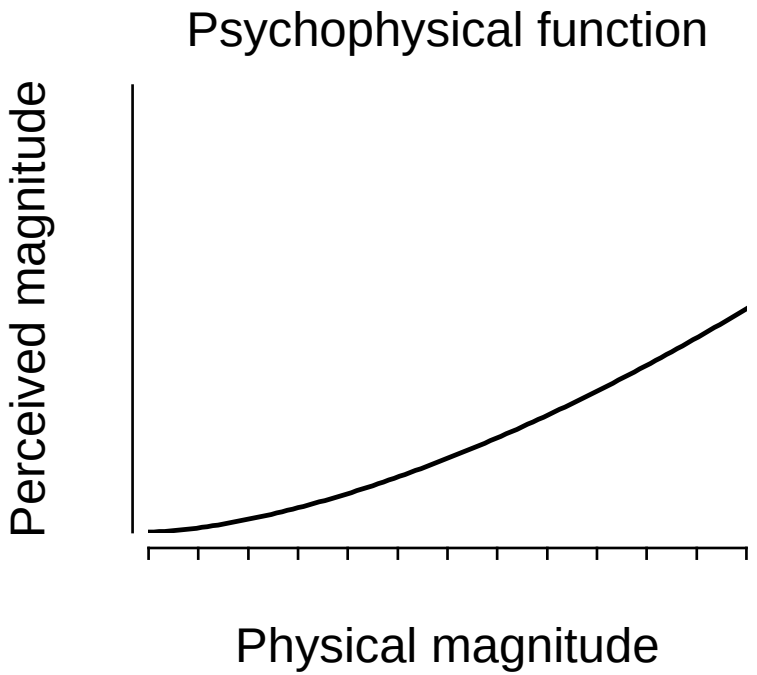




Two aspects of psychophysical performance

Relation between physical and perceived magnitude

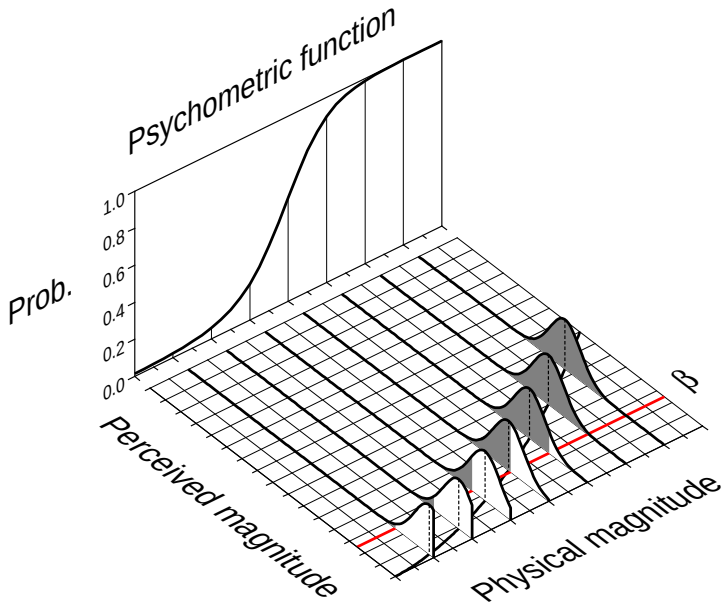


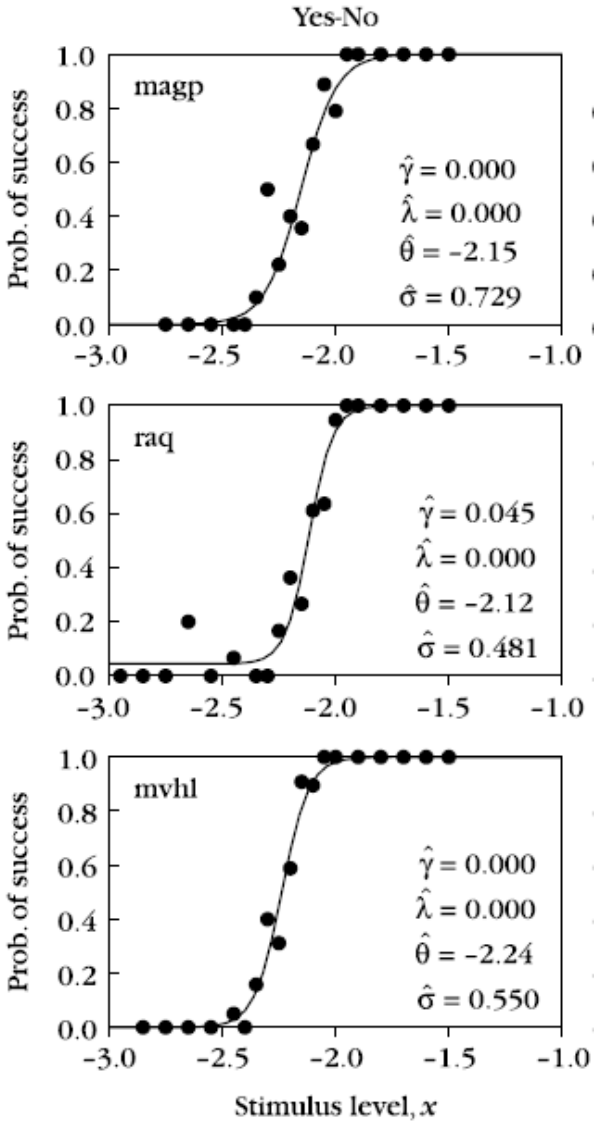


Two types of psychophysical tasks. 1: Single-presentation methods

Yes–No (binary detection)

García-Pérez, M. A. (2010). Denoising forced-choice detection data. *British Journal of Mathematical and Statistical Psychology*, *63*, 75–100

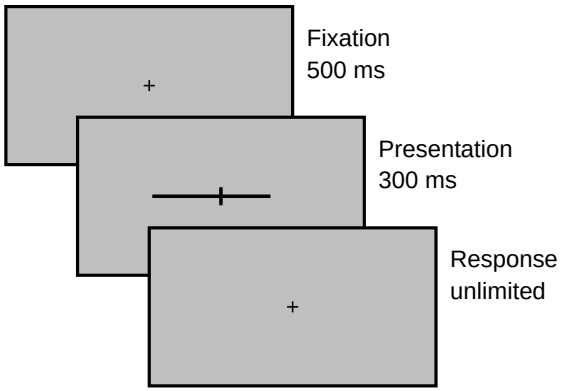


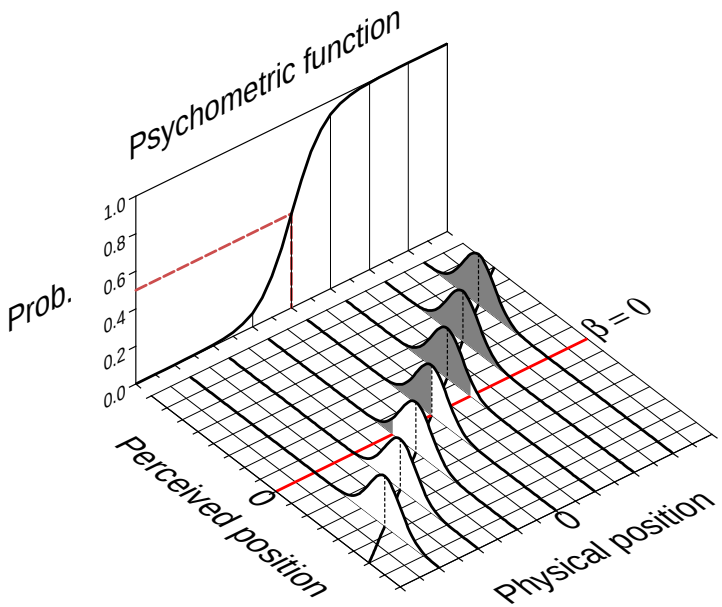


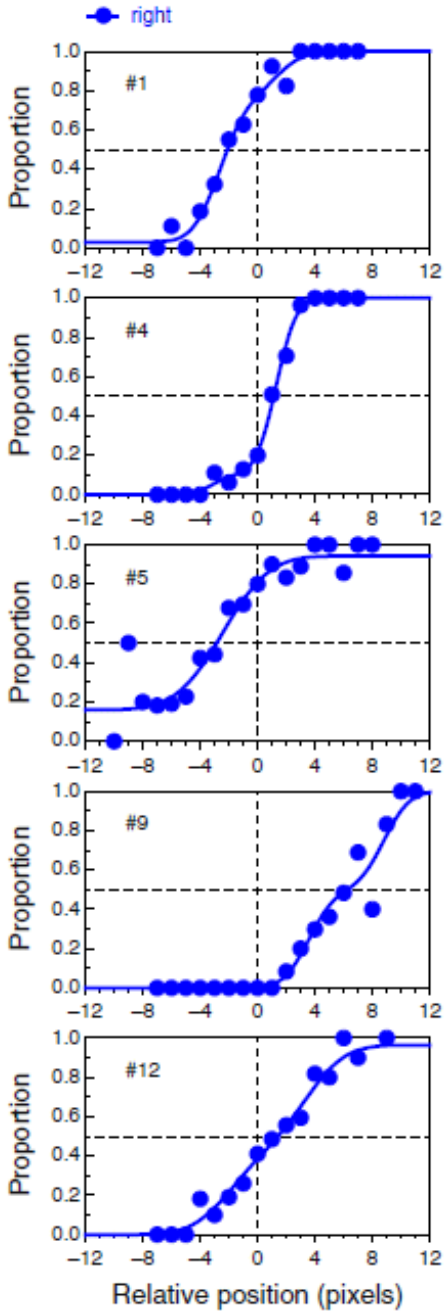
Two types of psychophysical tasks. 1: Single-presentation methods

Binary categorization

Spatial bisection: Is the vertical bar left or right of the center?







García-Pérez, M. A. & Peli, E. (2014). The bisection point across variants of the task. *Attention, Perception, & Psychophysics*, *76*, 1671–1697

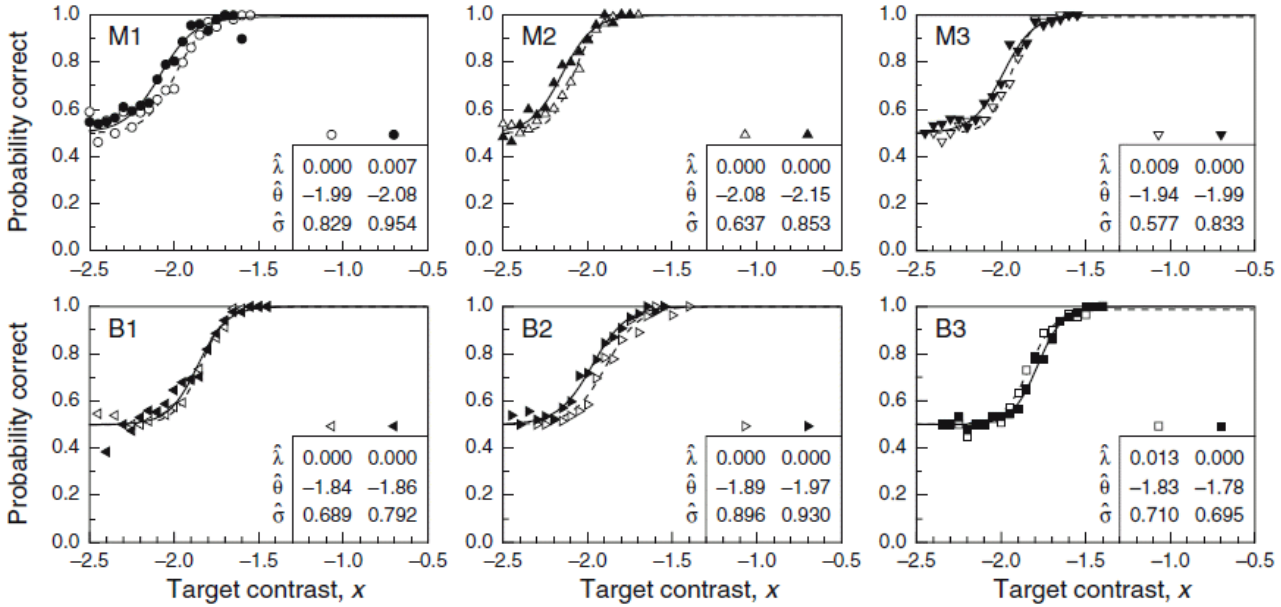
Two types of psychophysical tasks. 2: Dual-presentation methods

2AFC (binary detection)

test

null

García-Pérez, M. A. et al (2011). Psychometric functions for detection and discrimination with and without flankers. *Attention, Perception, & Psychophysics*, *73*, 829–853



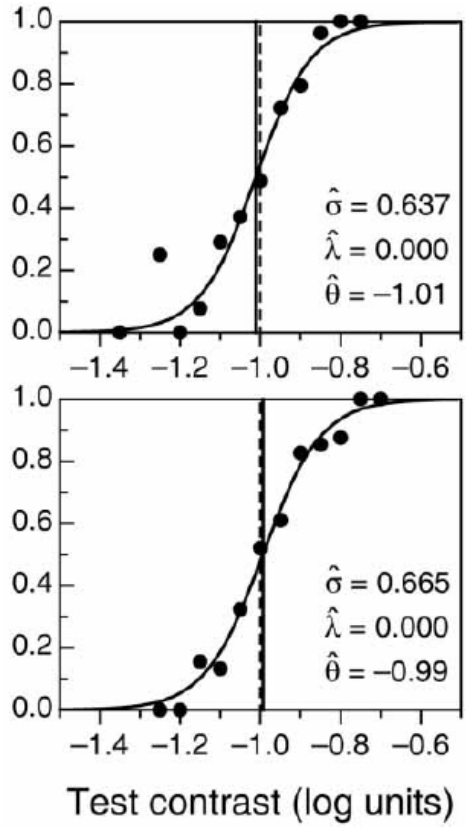
Two types of psychophysical tasks. 2: Dual-presentation methods

2AFC (binary discrimination)

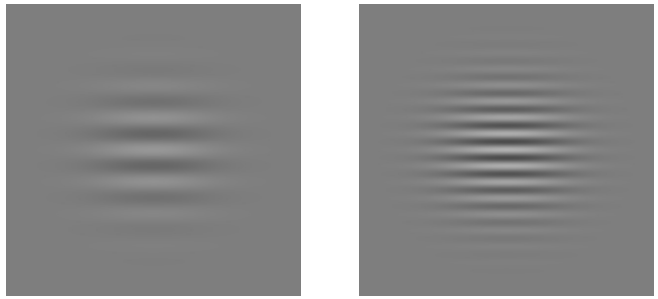
test

sample

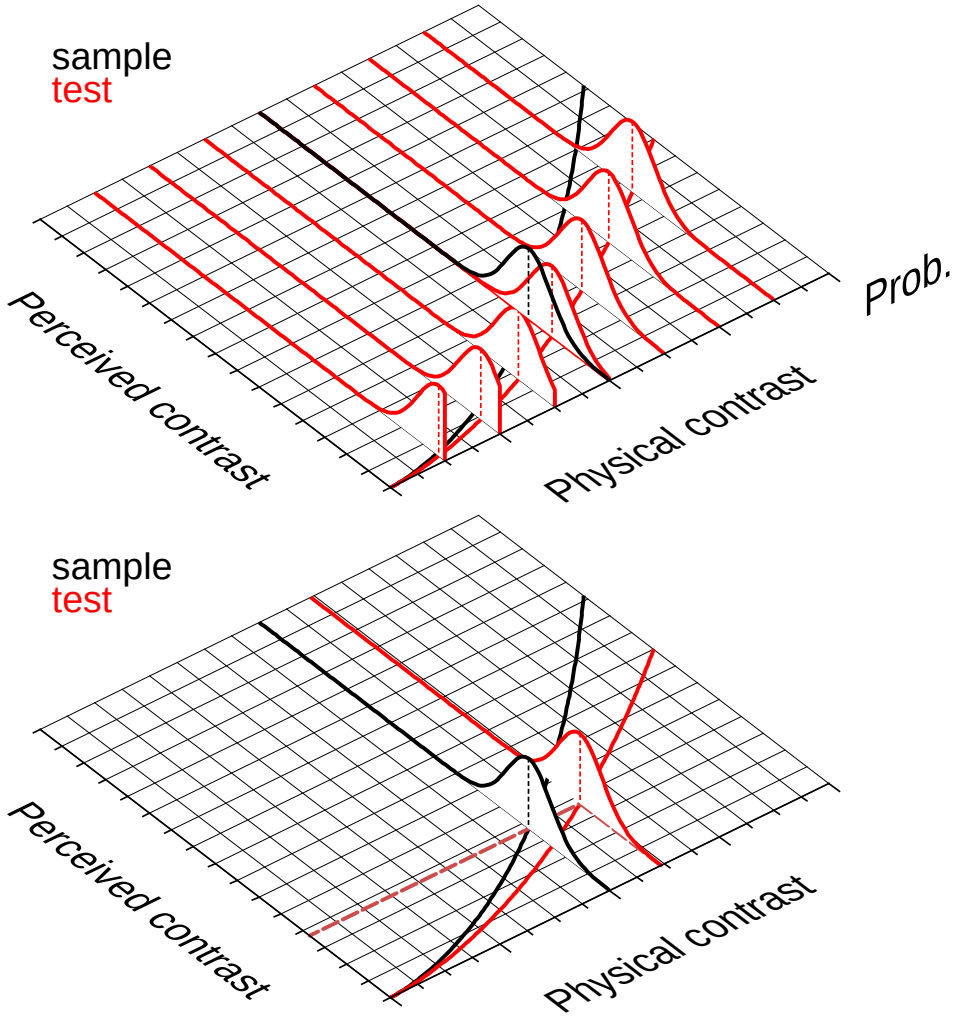
Alcalá-Quintana, R. & García-Pérez, M. A. (2011). A model for the time-order error in contrast discrimination. *Quarterly Journal of Experimental Psychology*, *64*, 1221–1248

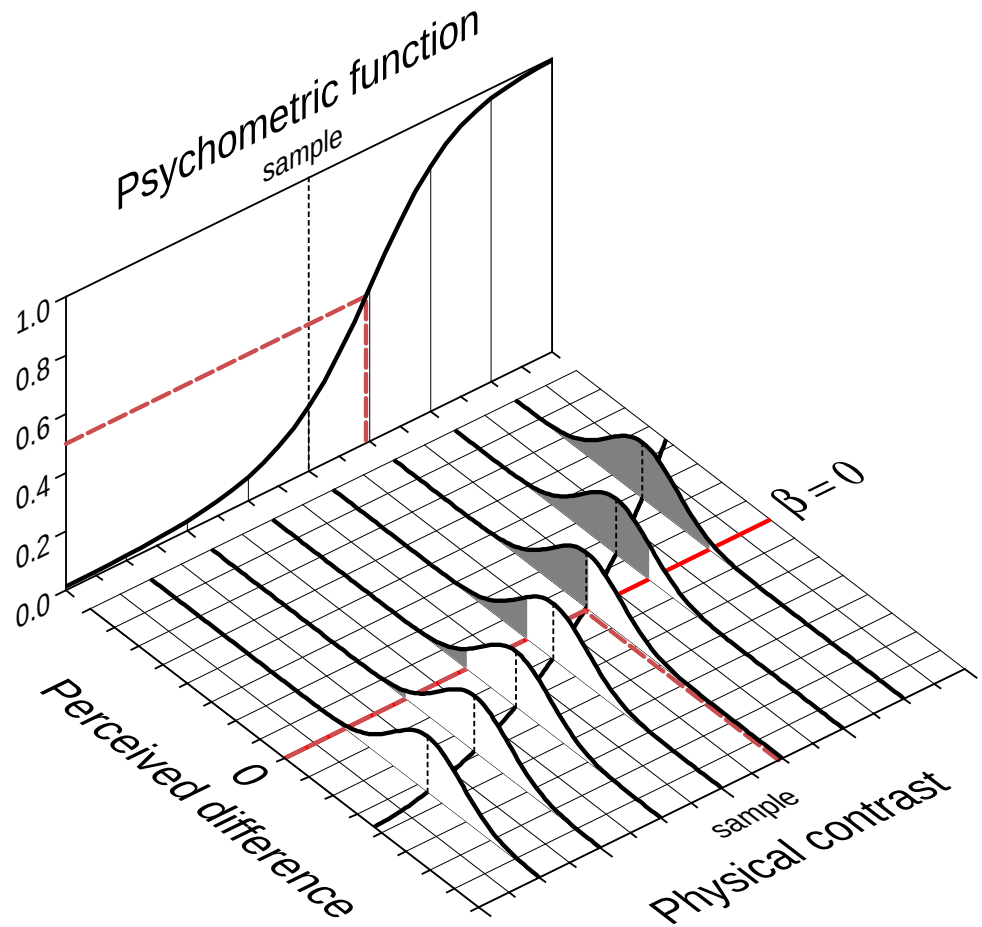


Paired comparisons in dual-presentation methods



sample test





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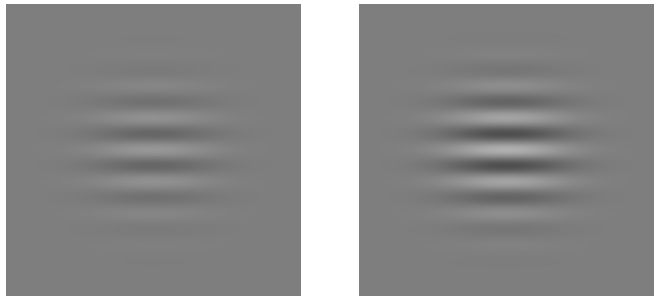
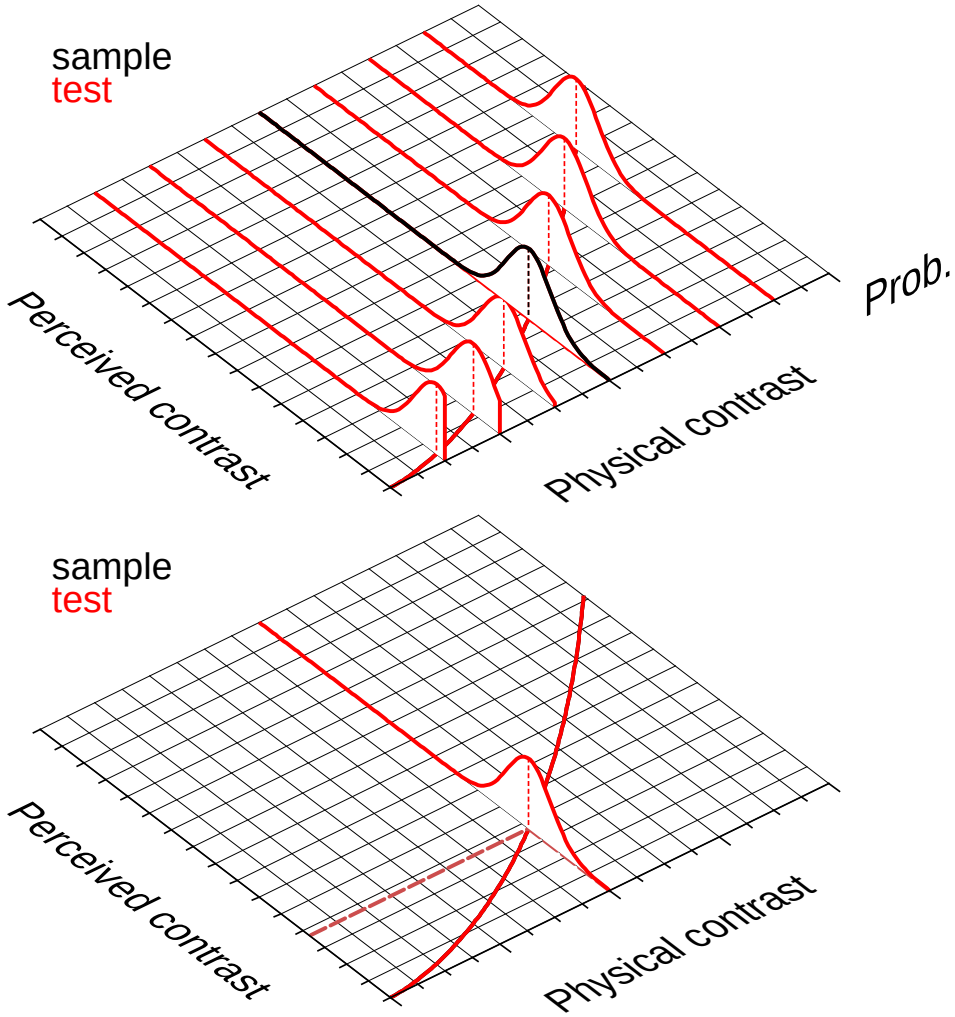
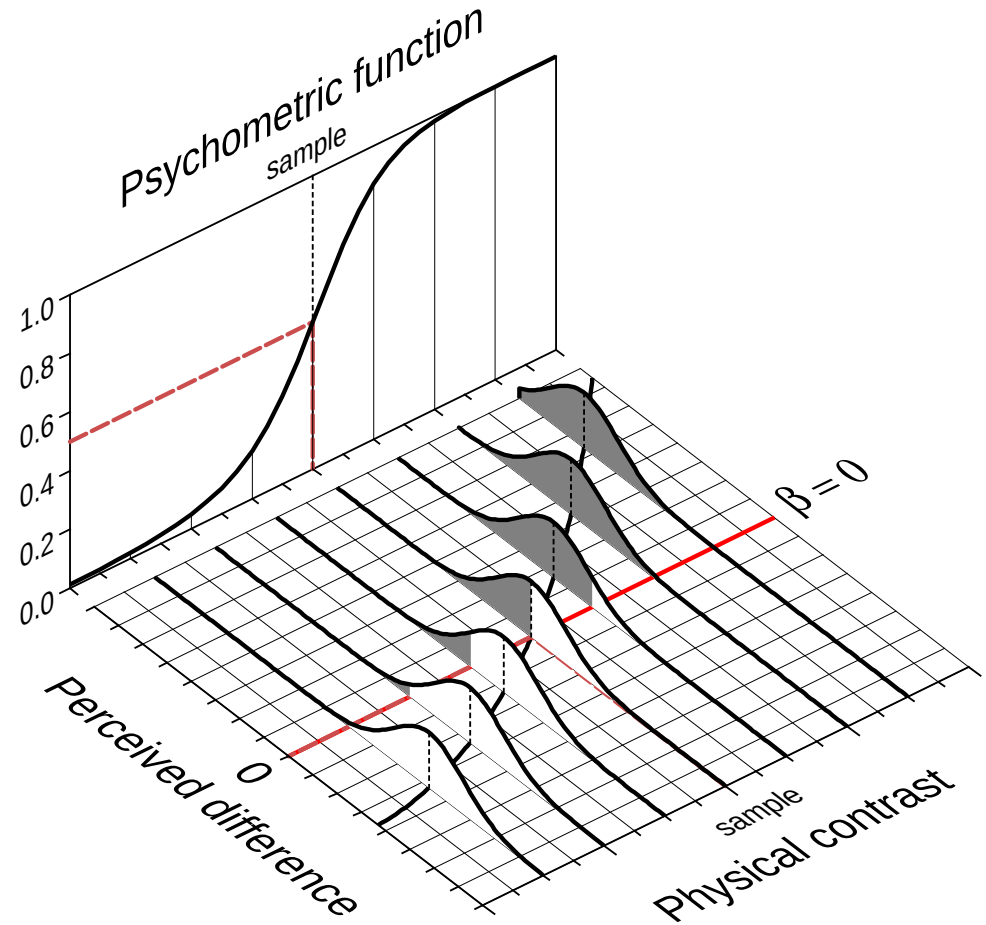


sample test



Prob.

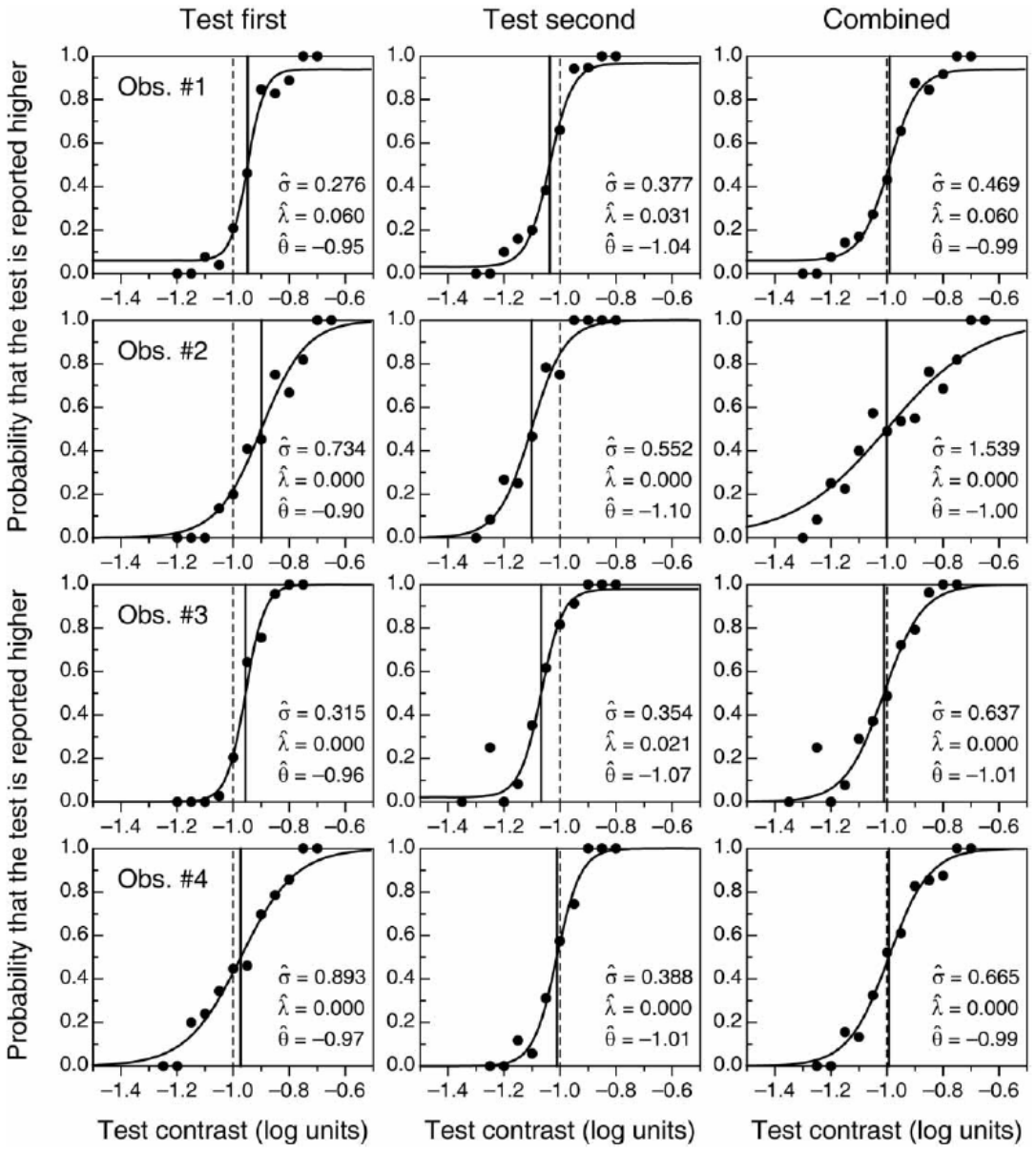


Some dual-presentation data that shatter this framework (order effects)

Alcalá-Quintana, R. & García-Pérez, M. A. (2011). A model for the time-order error in contrast discrimination. *Quarterly Journal of Experimental Psychology*, *64*, 1221–1248

test

sample



Some dual-presentation data that shatter this framework (order effects)

García-Pérez, M. A. (2000). Optimal setups for forced-choice staircases with fixed step sizes. *Spatial Vision*, *13*, 431–448

test

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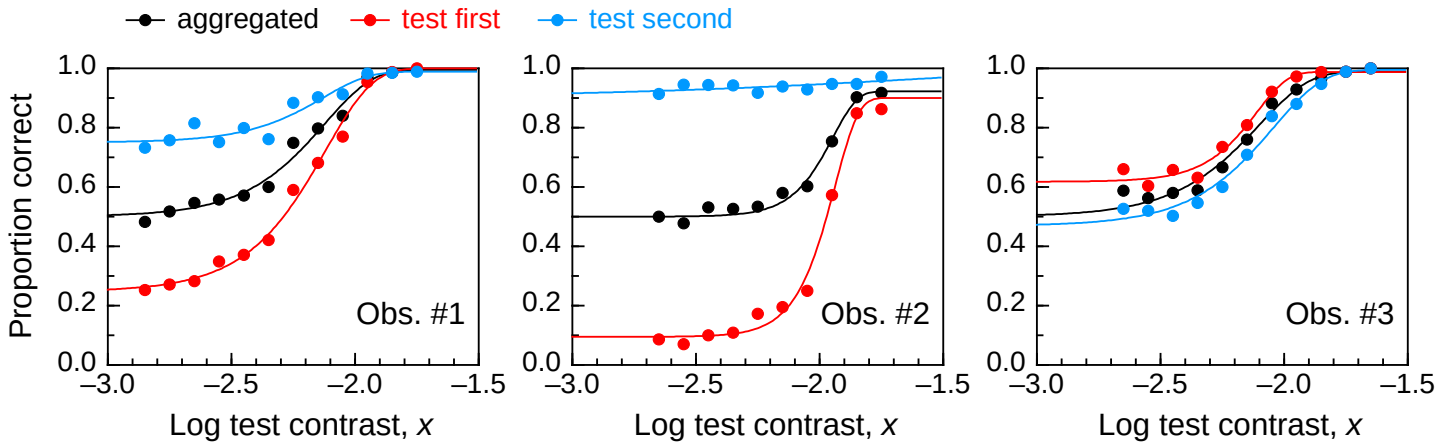

García-Pérez, M. A. & Alcalá-Quintana, R. (2011). Interval bias in 2AFC detection tasks: Sorting out the artifacts. *Attention, Perception, & Psychophysics*, *73*, 2332–2352

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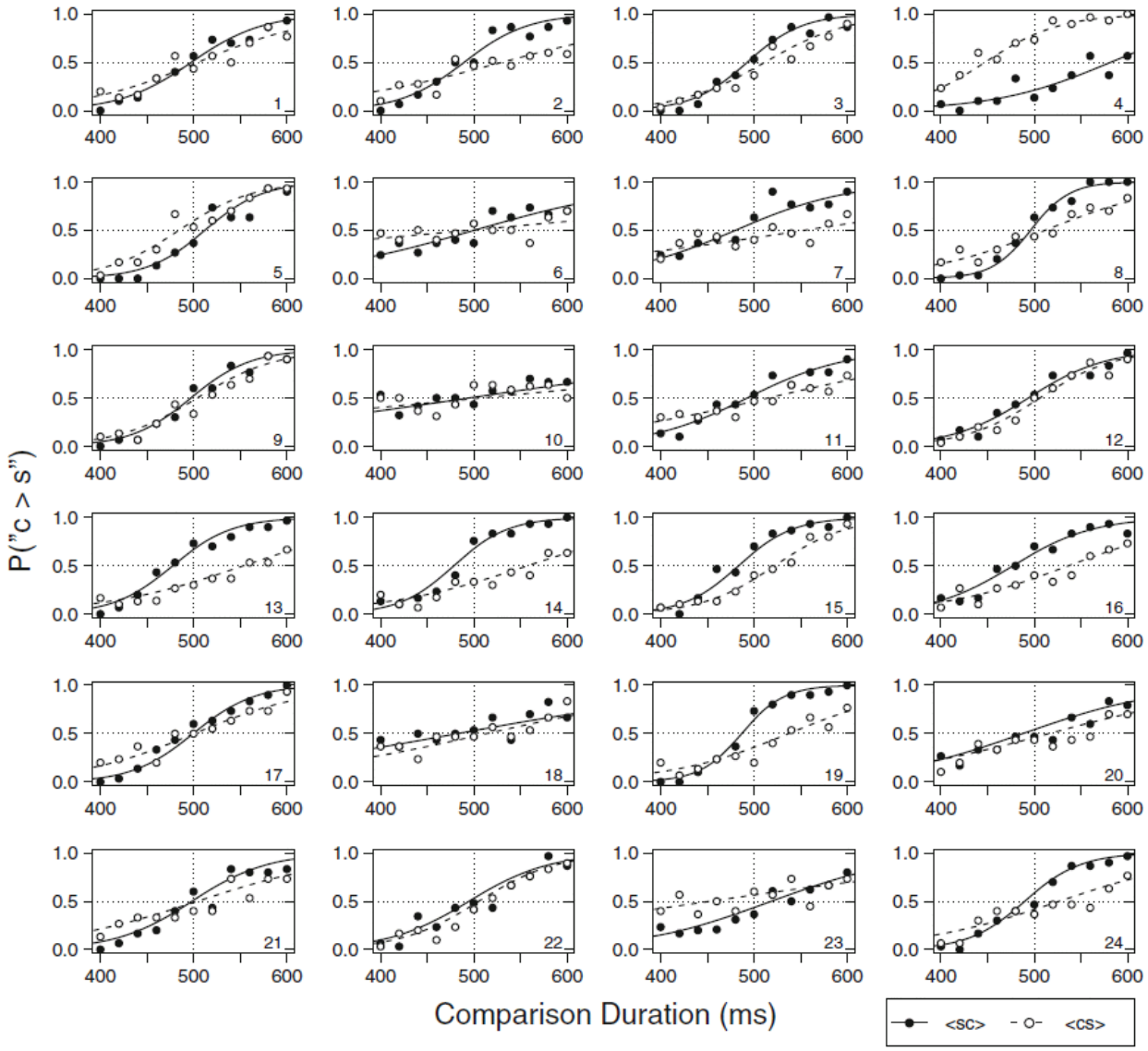
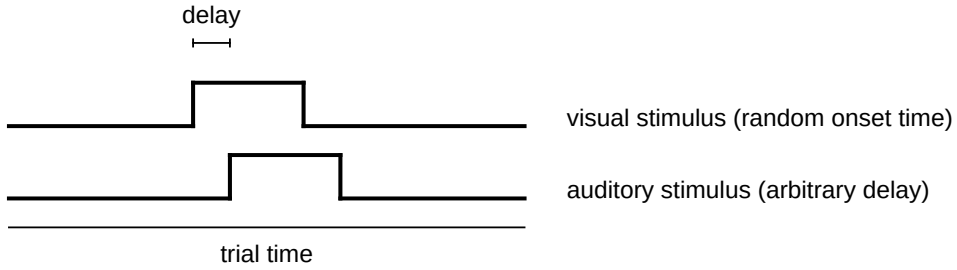
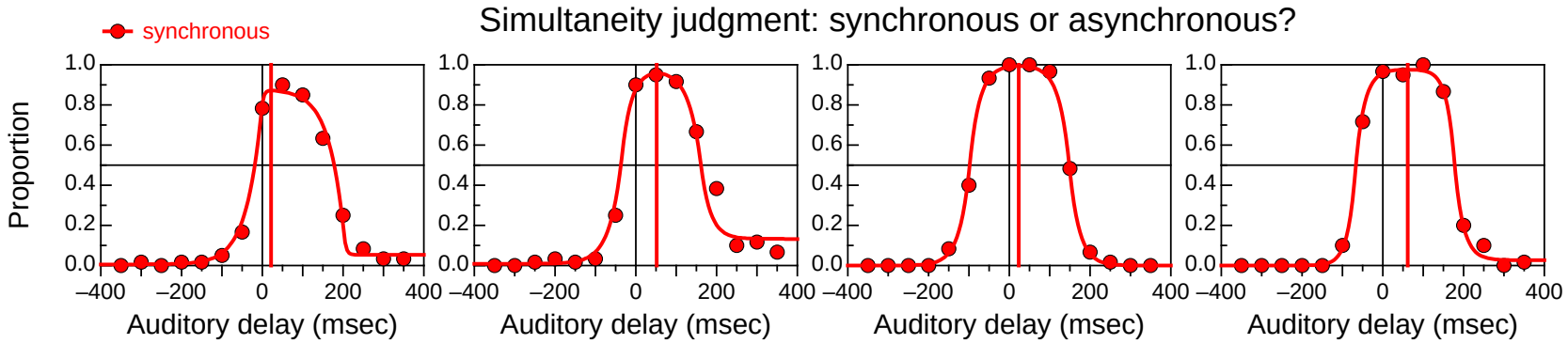
Dyjas, O. et al (2012). Trial-by-trial updating of an internal reference in discrimination tasks: Evidence from effects of stimulus order and trial sequence. *Attention, Perception, & Psychophysics*, *74*, 1819–1841

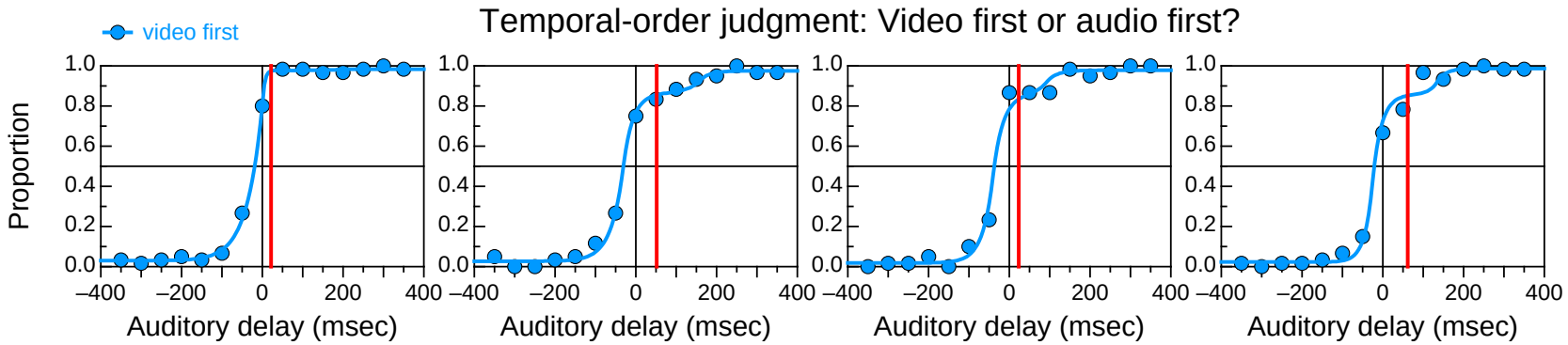


Some single-presentation data that shatter this framework (lateral shifts)

van Eijk, R. L. J. et al (2008). Audiovisual synchrony and temporal order judgments: Effects of experimental method and stimulus type. *Perception & Psychophysics*, *70*, 955–968







Some single-presentation data that shatter this framework (lateral shifts)

Morgan, M. J. et al (2012). Observers can voluntarily shift their psychometric function without losing sensitivity. *Attention, Perception, & Psychophysics*, *74*, 185–193

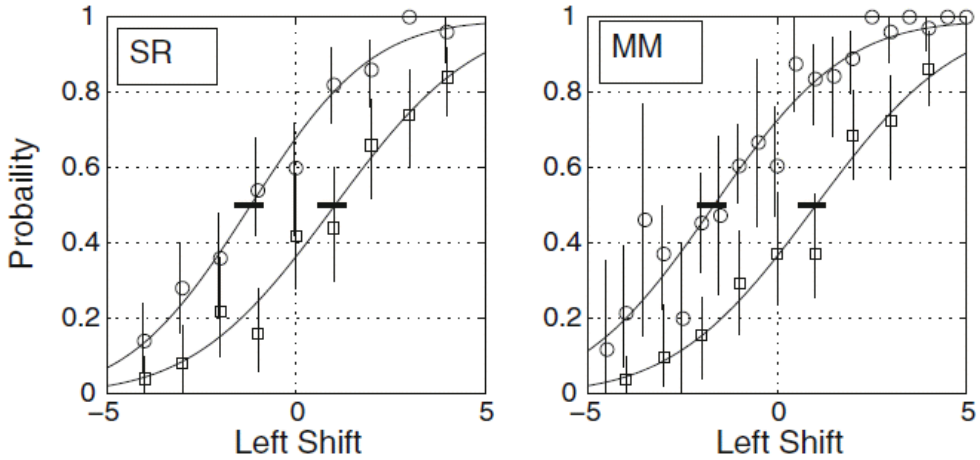


Fig. 2 The figure shows data from the bisection task, presented with the same conventions as in Fig. 1

- ○ Natural
- □ Respond "left" when uncertain

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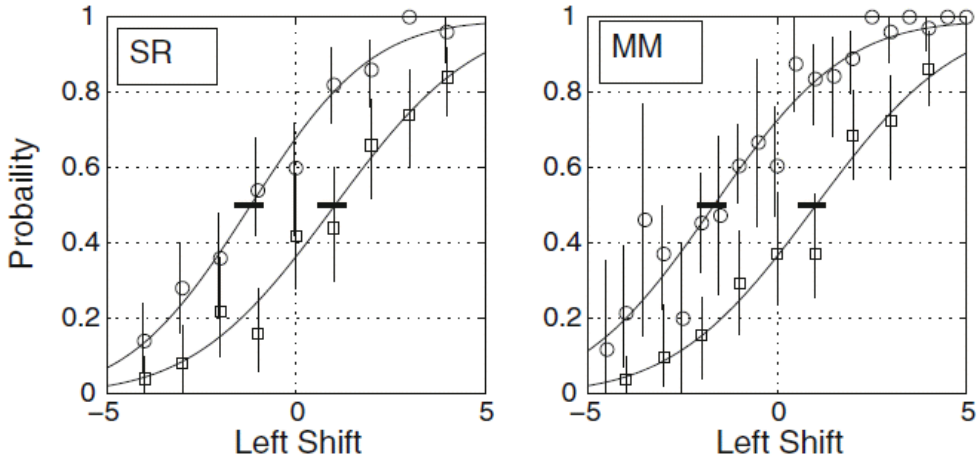

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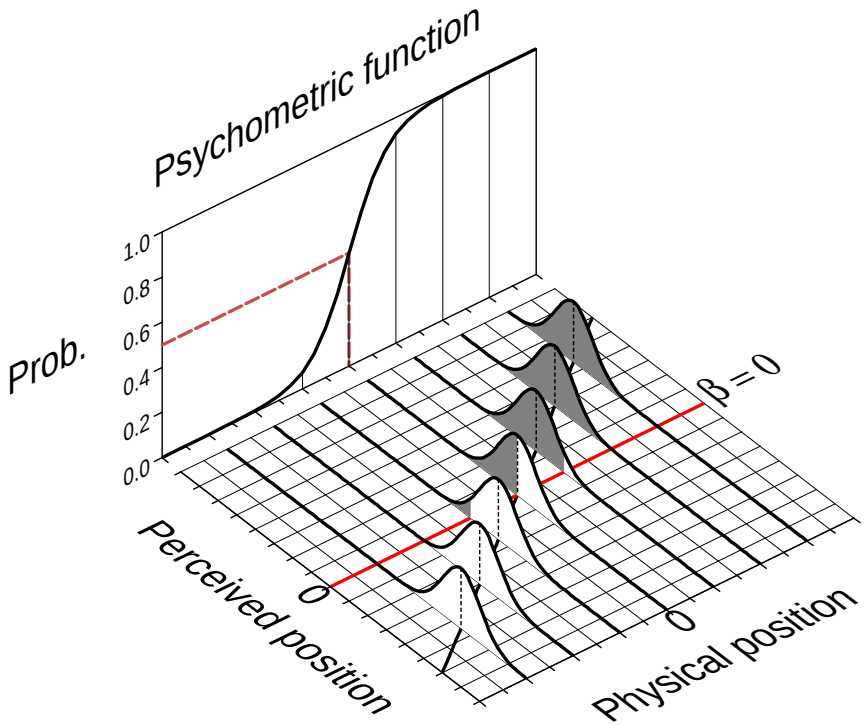

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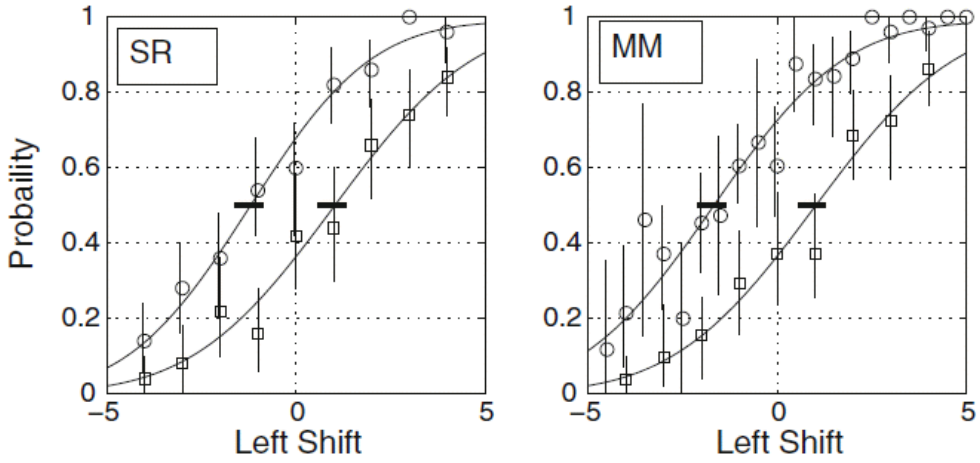

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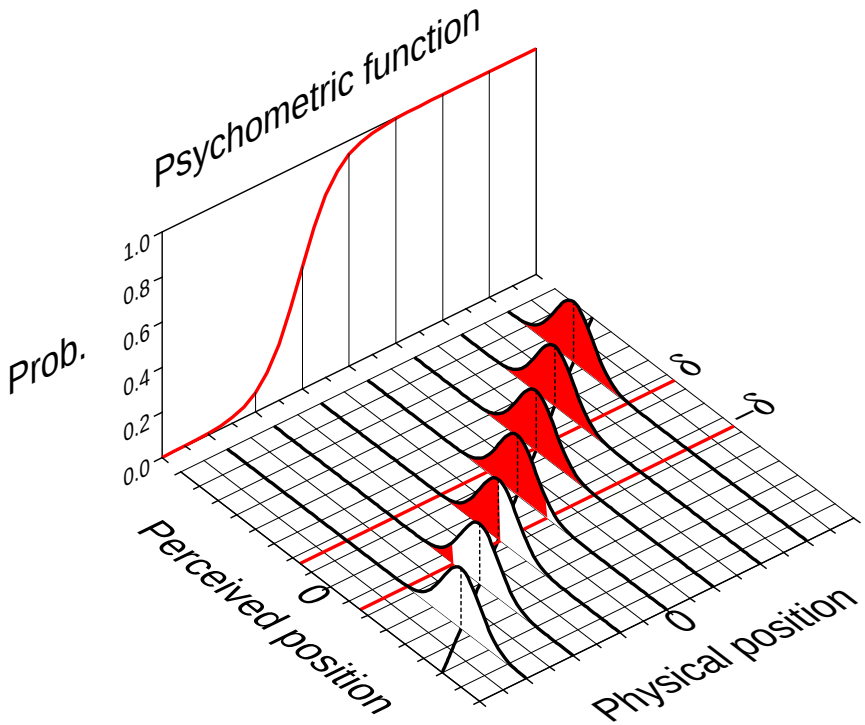

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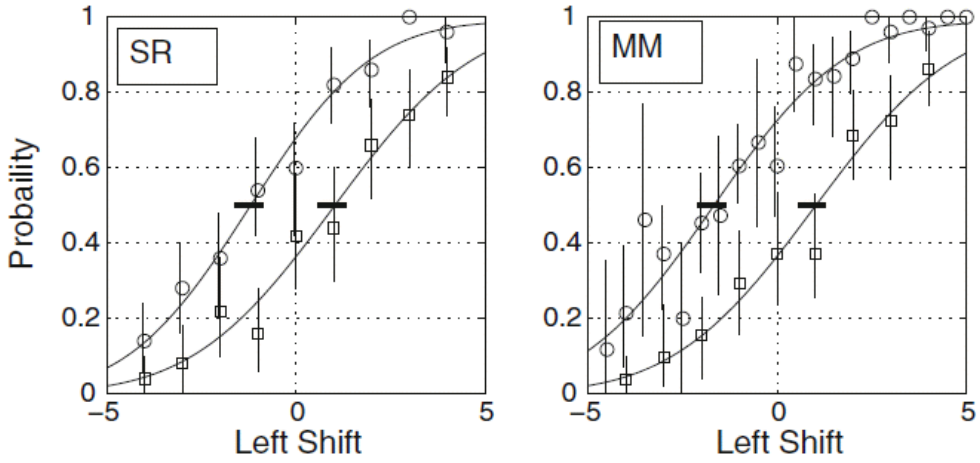

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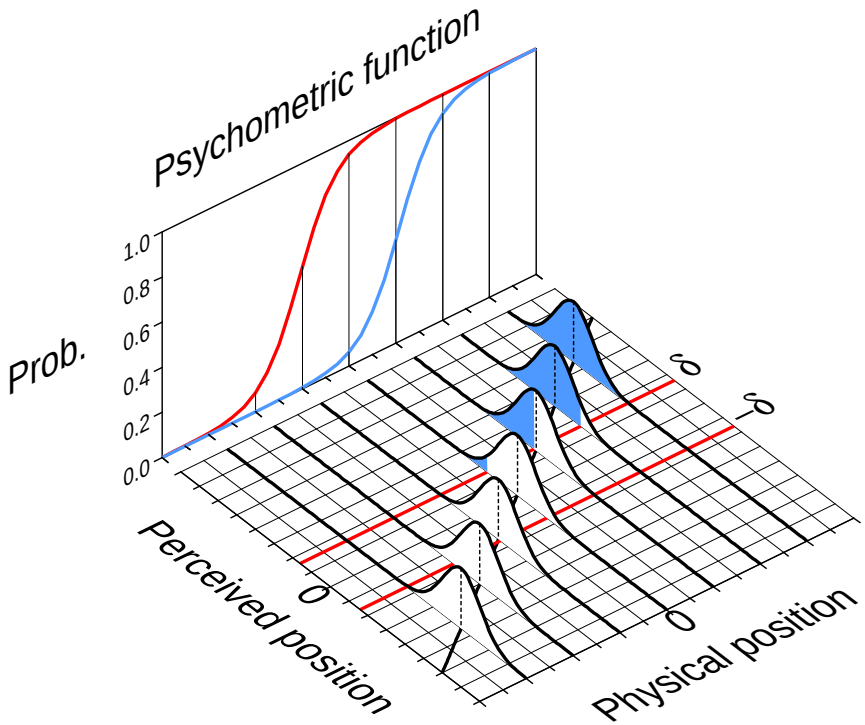

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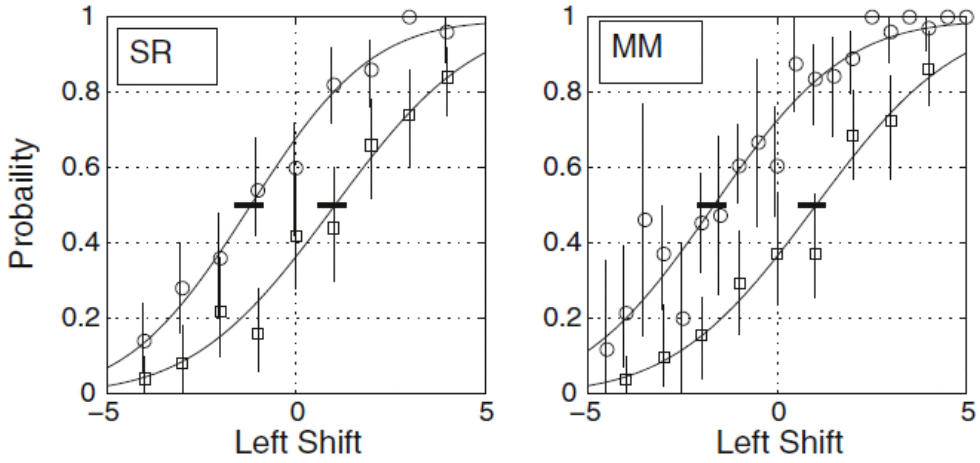

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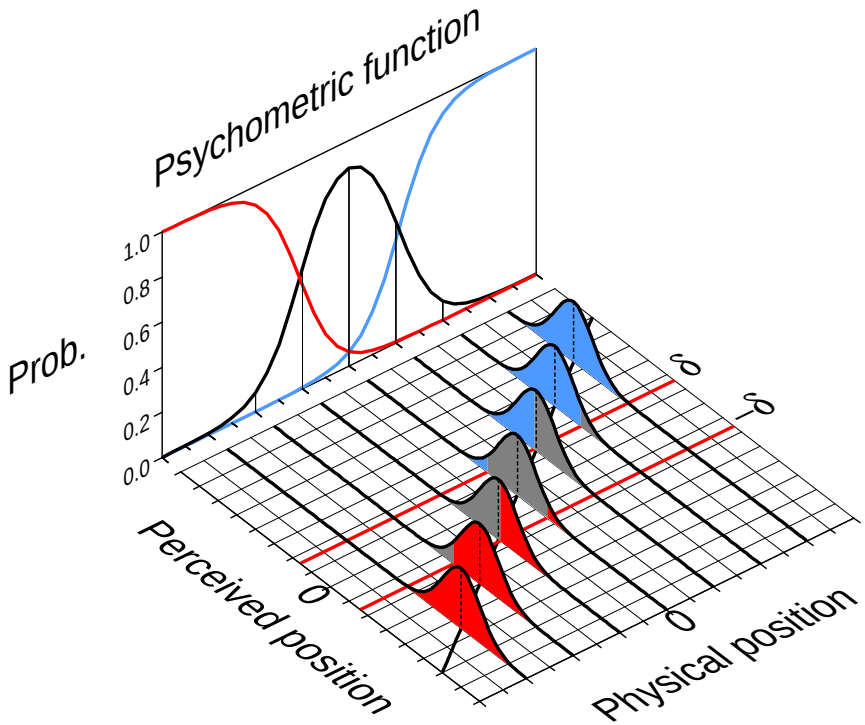
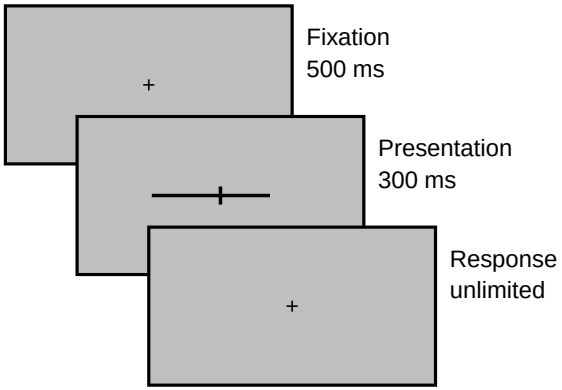


Some single-presentation data that shatter this framework (lateral shifts)

Ternary categorization

Spatial bisection: Is the vertical bar left, right, or at the center?



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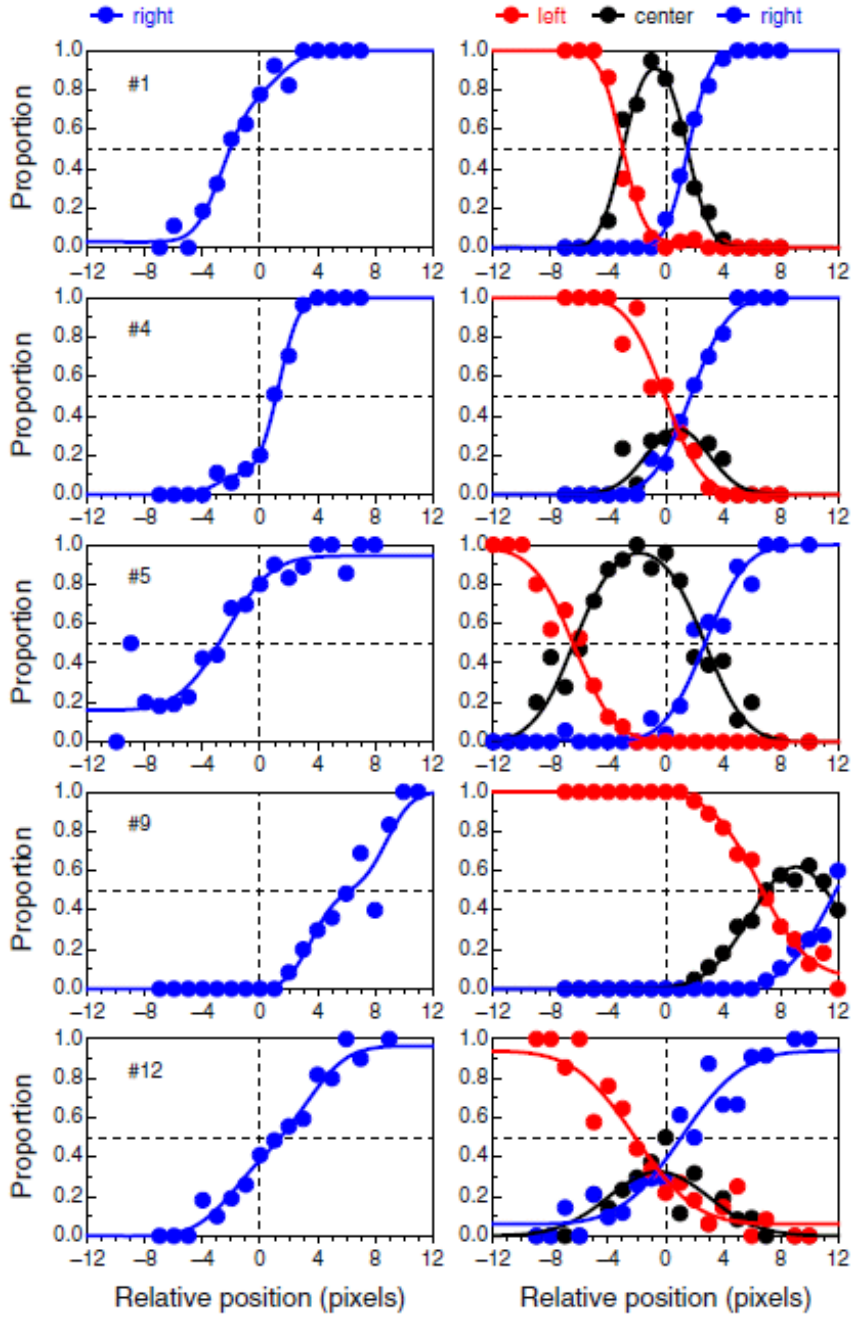
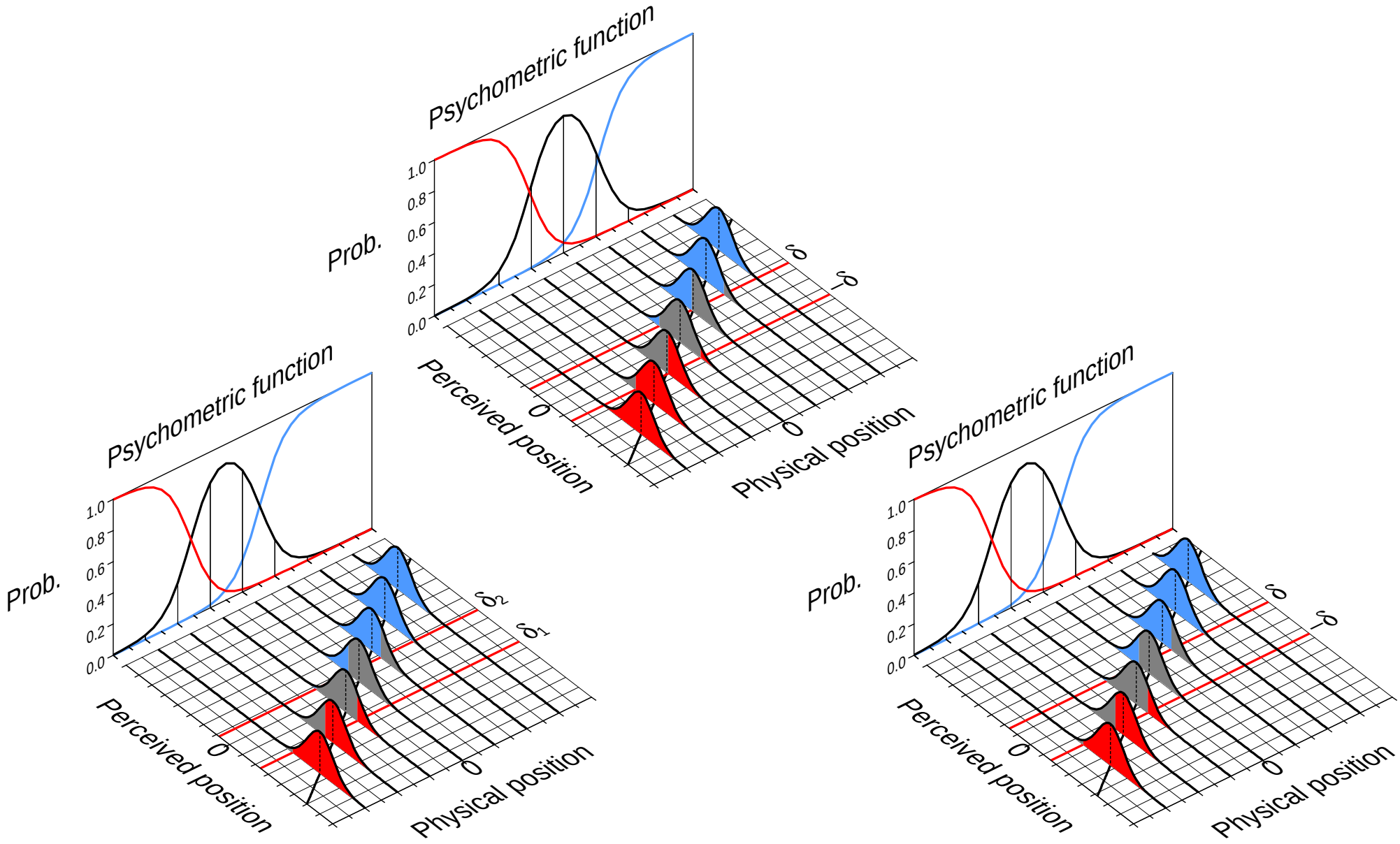


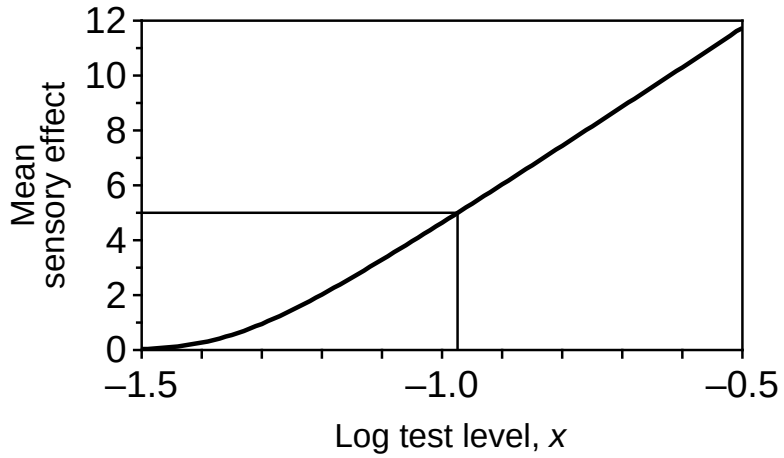
Decisional bias: An inescapable problem of single-presentation methods



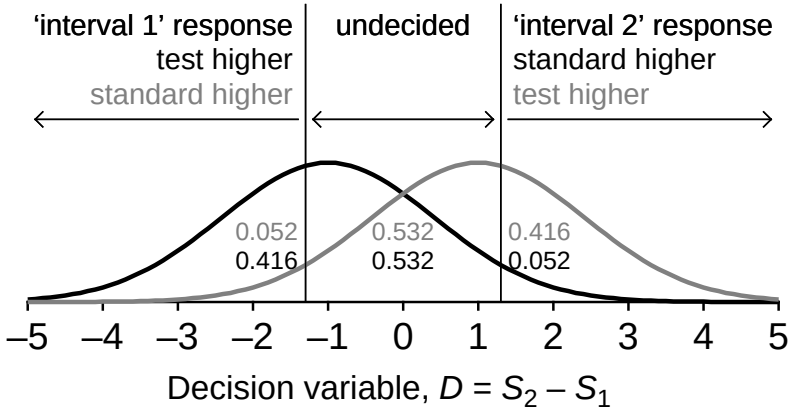
García-Pérez, M. A. & Alcalá-Quintana, R. (2013). Shifts of the psychometric function: Distinguishing bias from perceptual effects. *Quarterly Journal of Experimental Psychology*, *66*, 319–337

How the three-response format separates sensory and decisional influences in dual-presentation methods

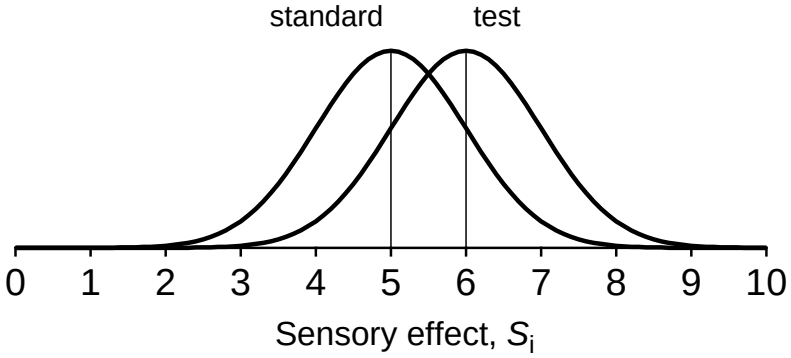
Psychophysical function

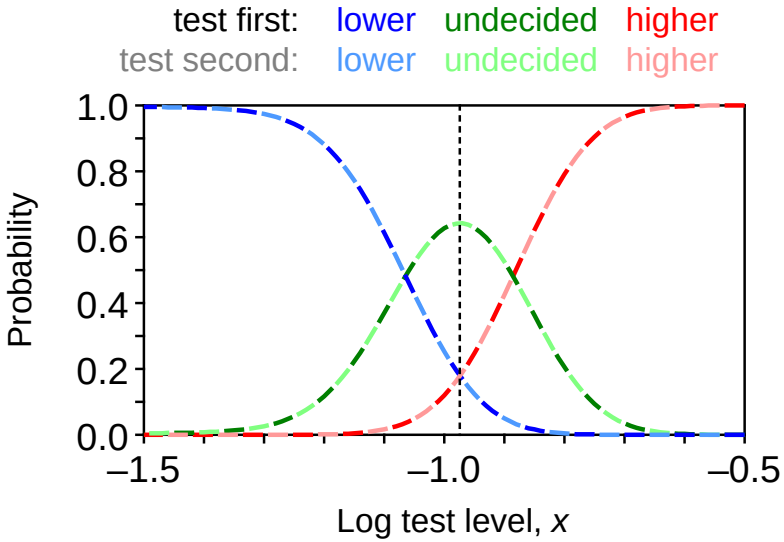


Decision space; test first, test second



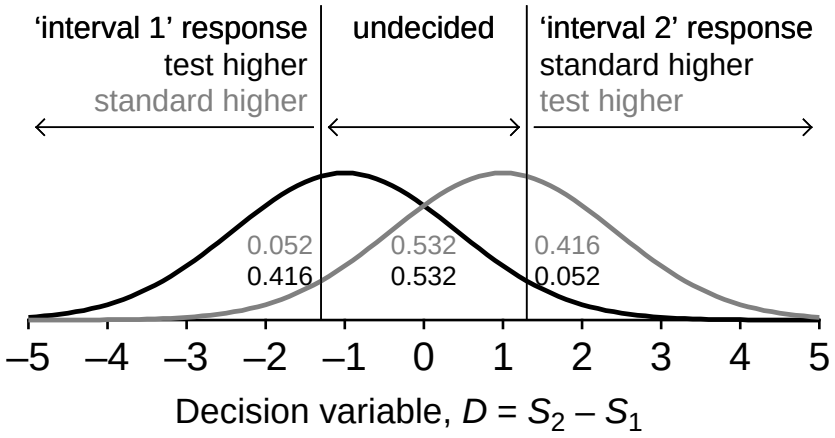
Distributions of sensory effects





How the three-response format separates sensory and decisional influences in dual-presentation methods

Decision space; test first, test second



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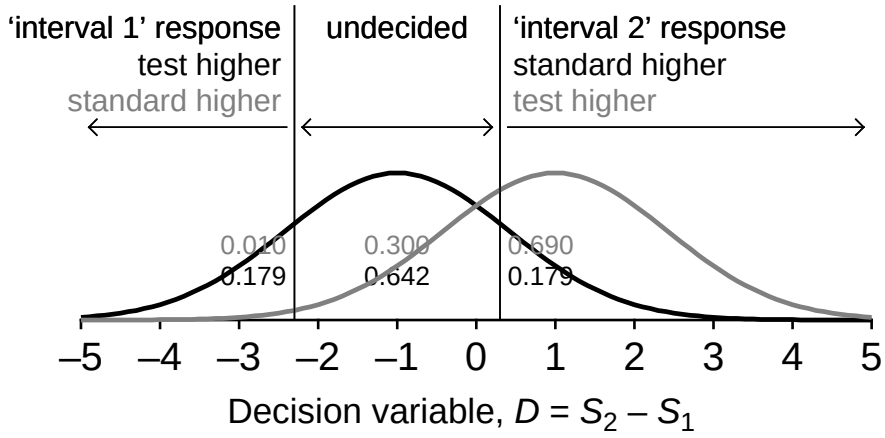
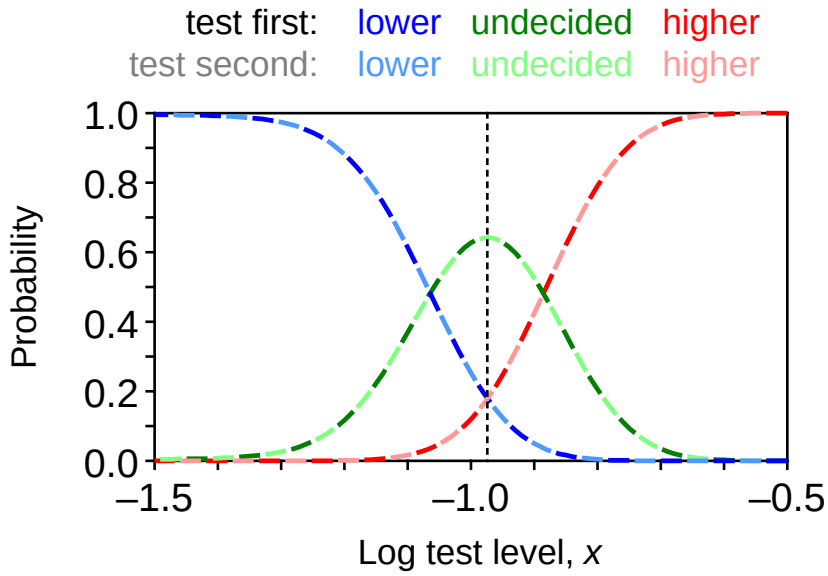
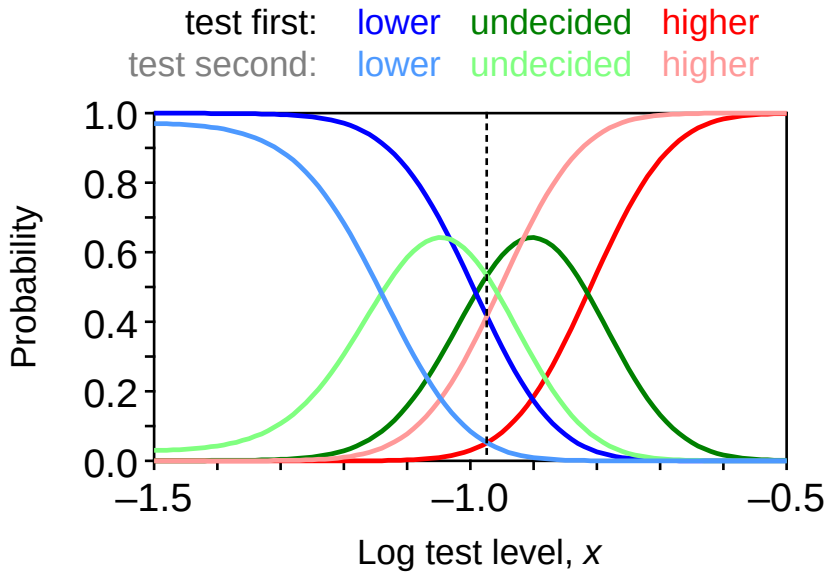
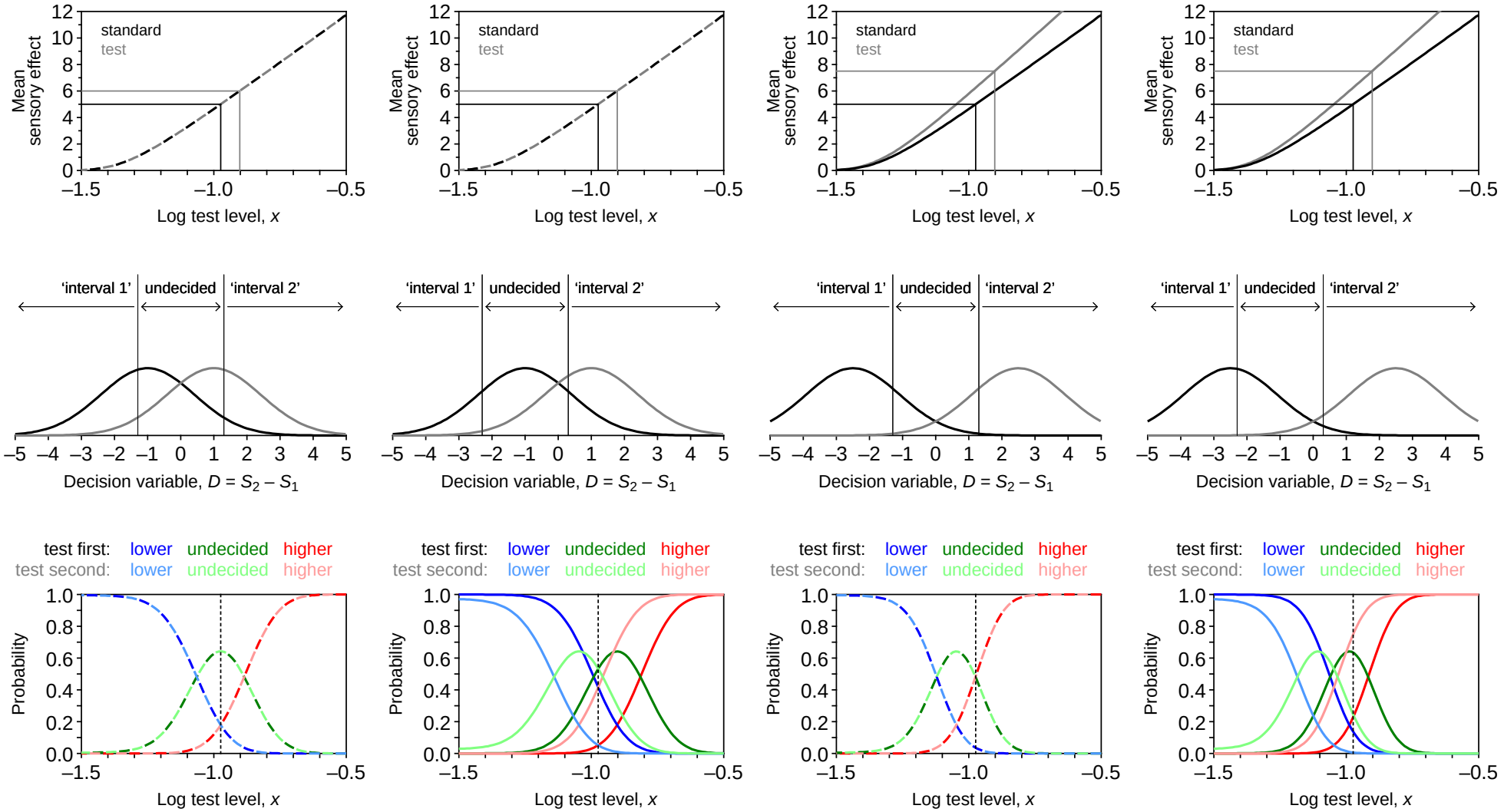






How the three-response format separates sensory and decisional influences in dual-presentation methods



no perceptual effect
no decisional bias

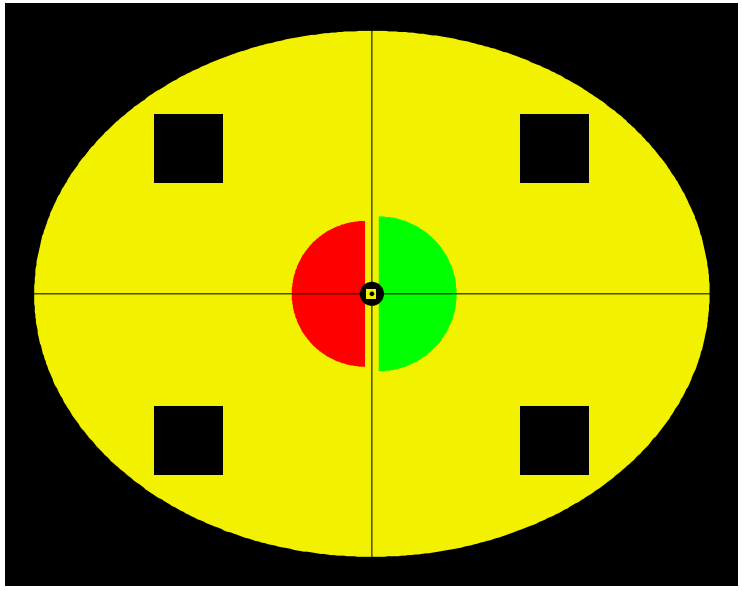
no perceptual effect
decisional bias

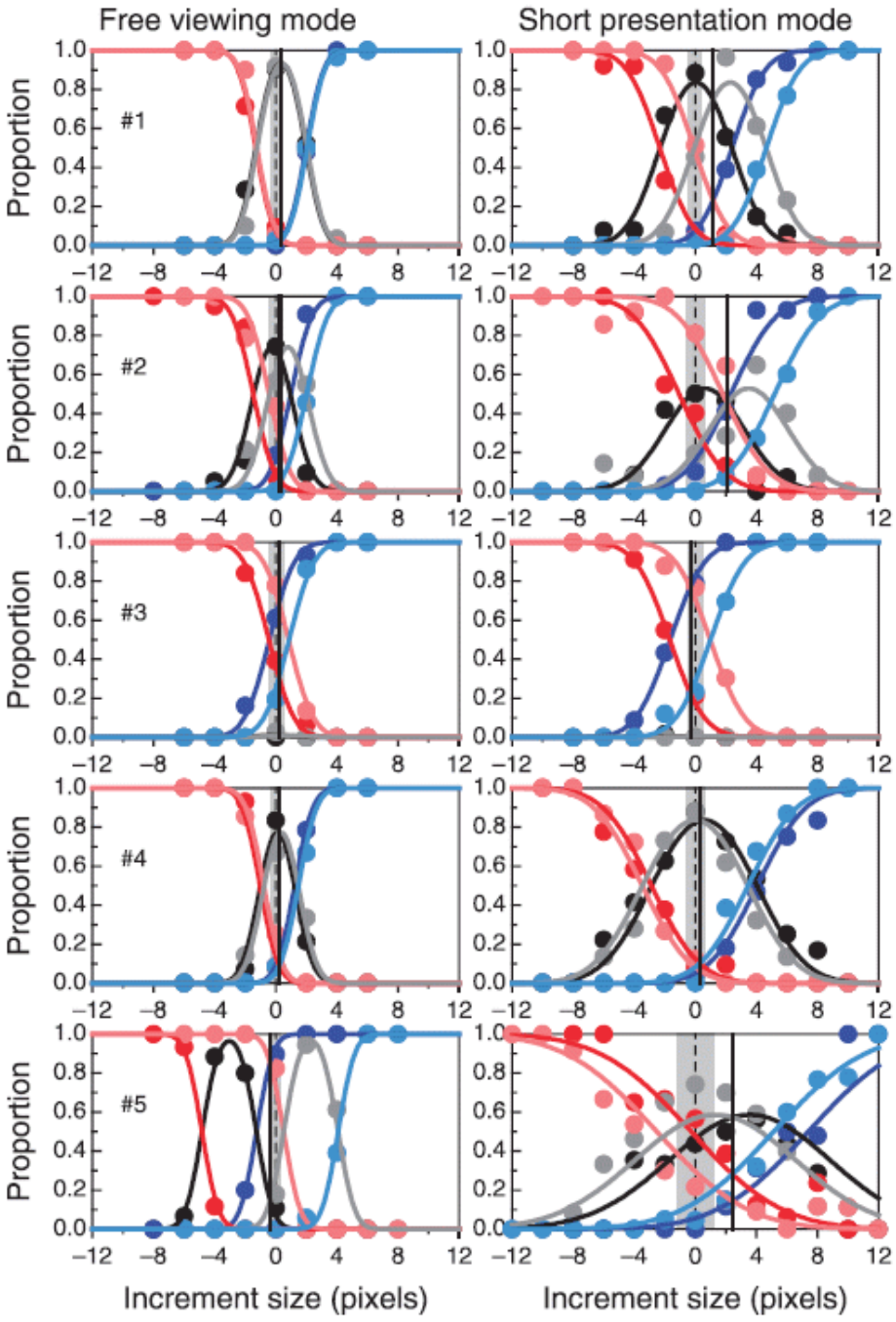
perceptual effect
no decisional bias

perceptual effect
decisional bias

Some empirical data

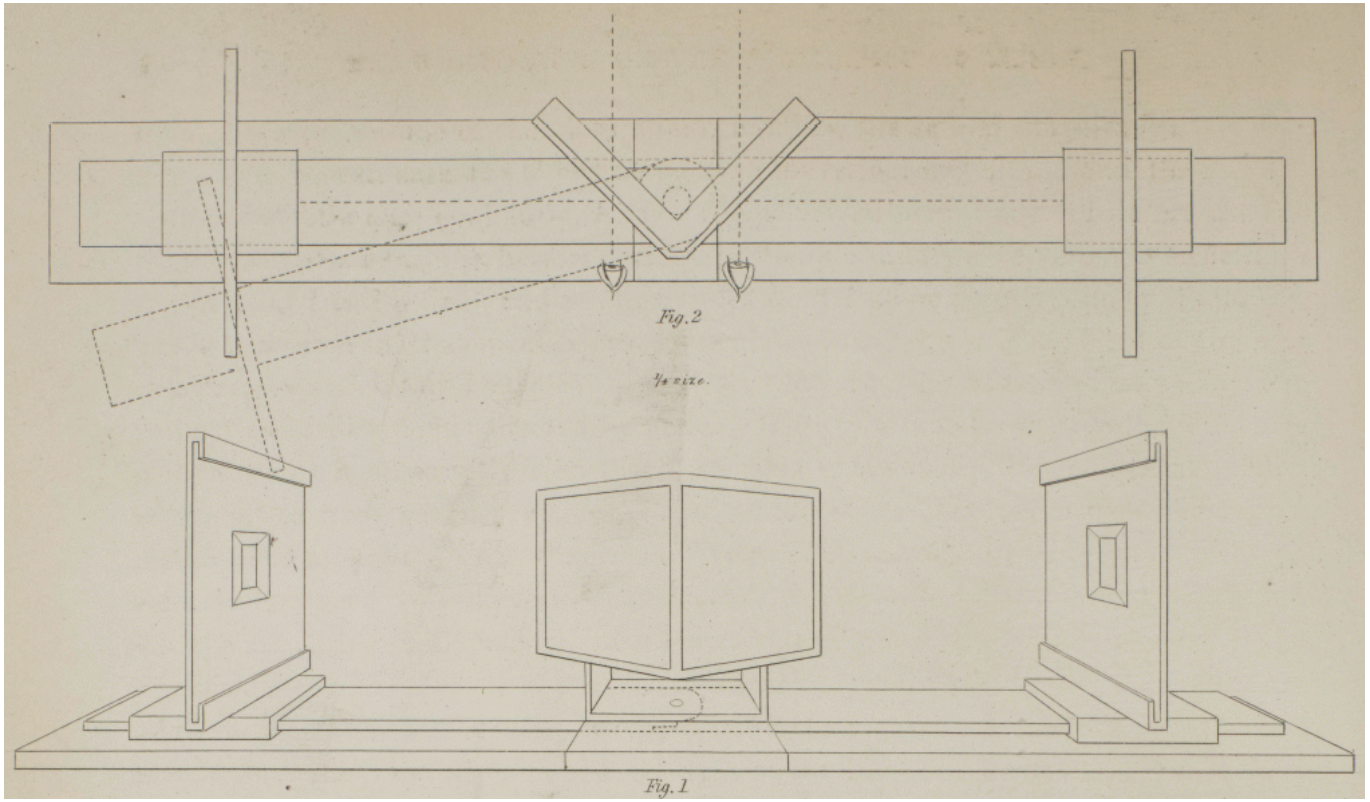
García-Pérez, M. A. & Peli, E. (2015). Aniseikonia tests: The role of viewing mode, response bias, and size–color illusions. *Translational Vision Science and Technology*, *4*(3) 9

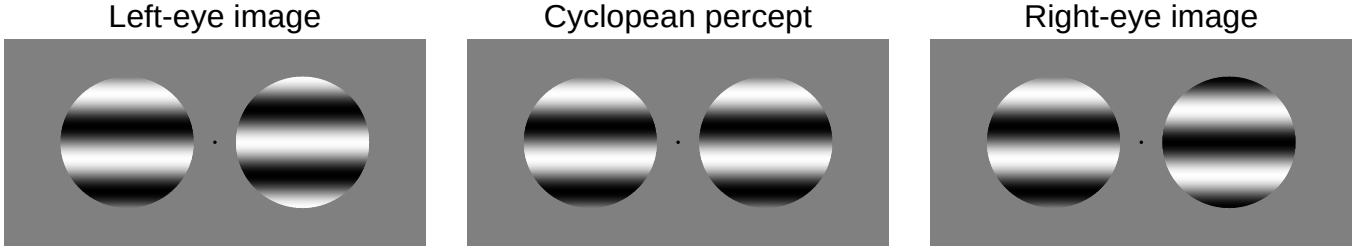




Some empirical data

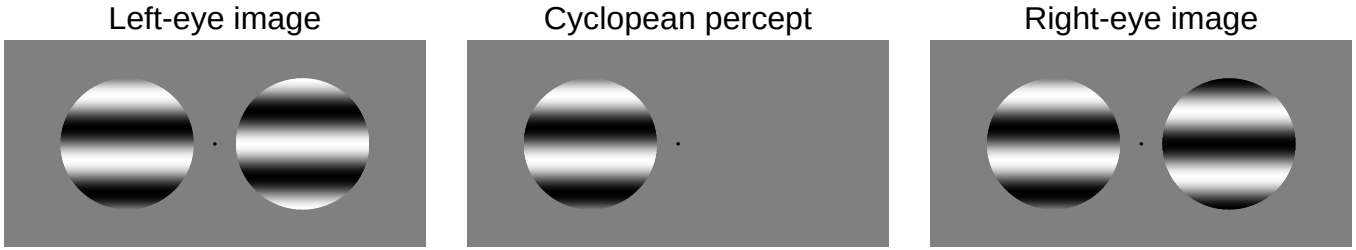
García-Pérez, M. A. & Peli, E. (2019). Psychophysical tests do not identify ocular dominance consistently. *i-Perception*, *10*, 2





Some empirical data

García-Pérez, M. A. & Peli, E. (2019). Psychophysical tests do not identify ocular dominance consistently. *i-Perception*, *10*, 2



$$a_L \sin(x+\varphi_L) + a_R \sin(x+\varphi_R) = a \sin(x+\varphi)$$

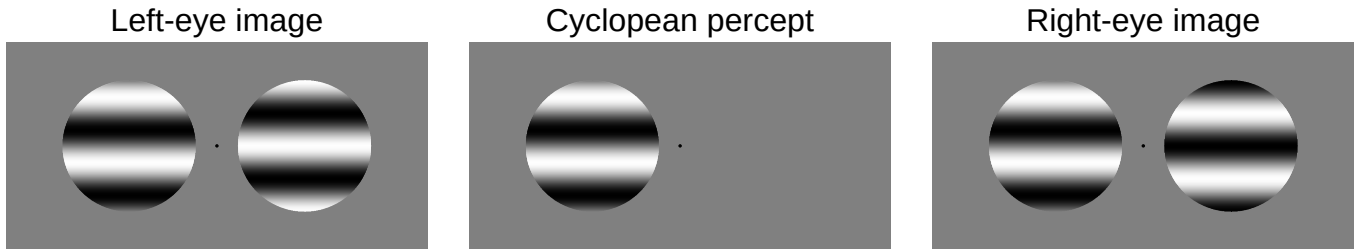
with

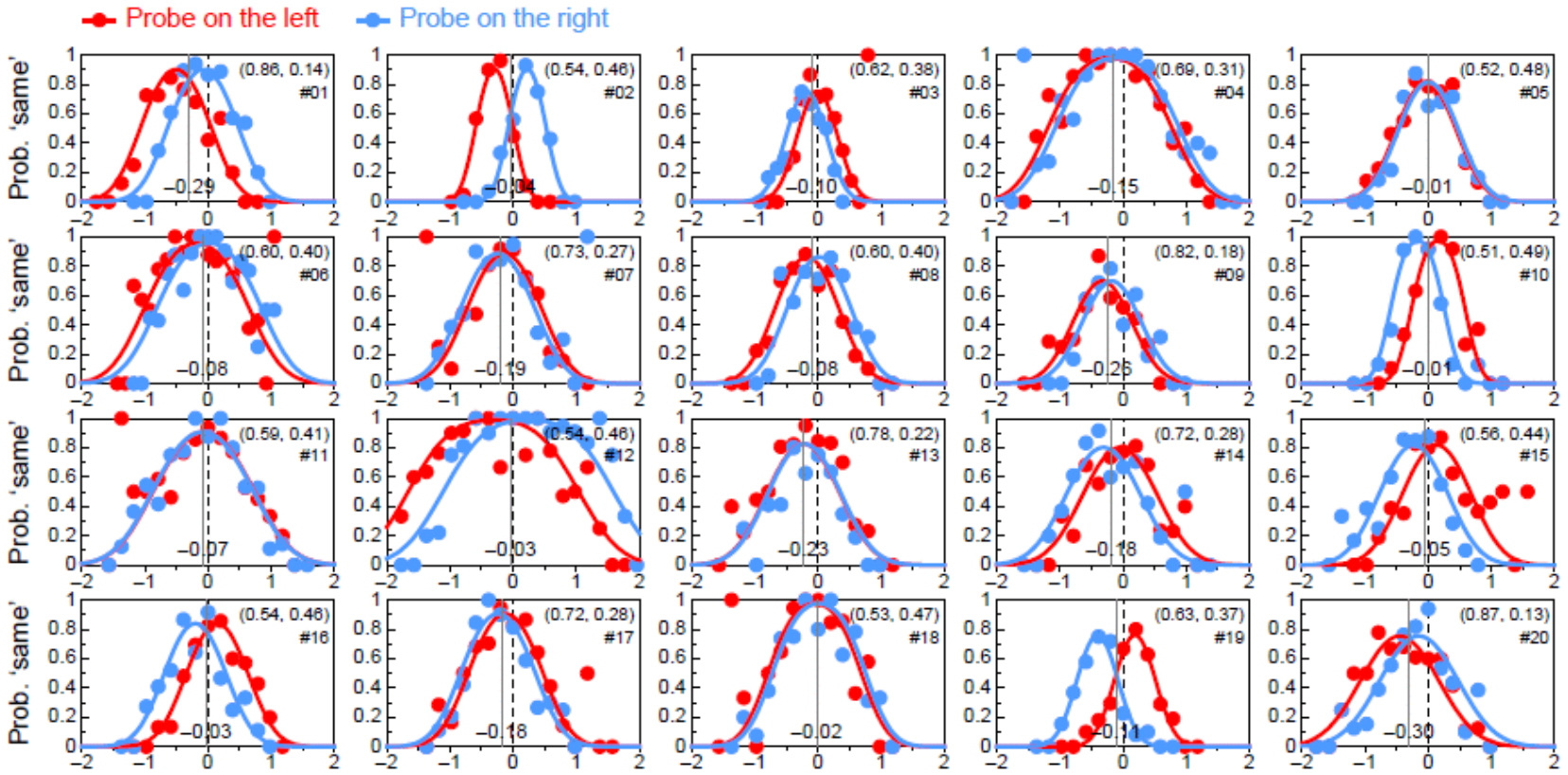
$$a = \sqrt{a_L^2 + a_R^2 + 2a_L a_R \cos(\varphi_R - \varphi_L)}$$

$$\varphi = \varphi_L + \tan^{-1}\left(\frac{a_R \sin(\varphi_R - \varphi_L)}{a_L + a_R \cos(\varphi_R - \varphi_L)} \right)$$

Some empirical data

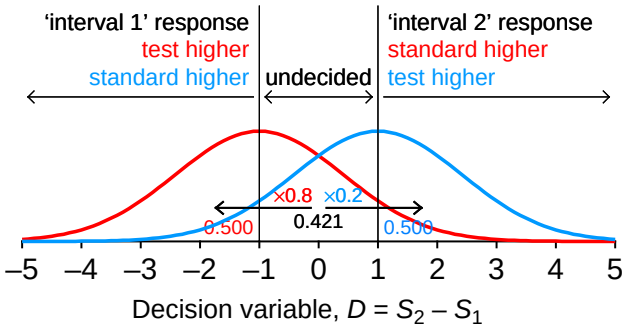
García-Pérez, M. A. & Peli, E. (2019). Psychophysical tests do not identify ocular dominance consistently. *i-Perception*, *10*, 2



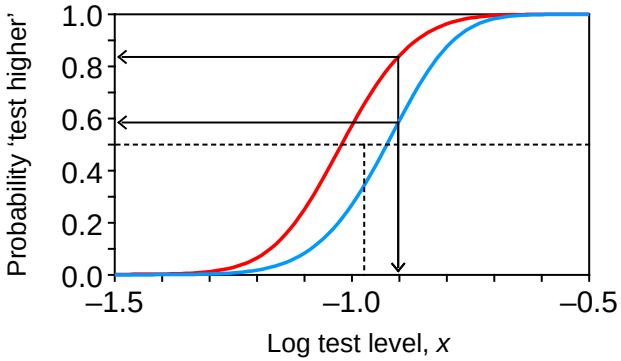


How indecision explains order effects in binary tasks
Which stimulus has higher contrast?

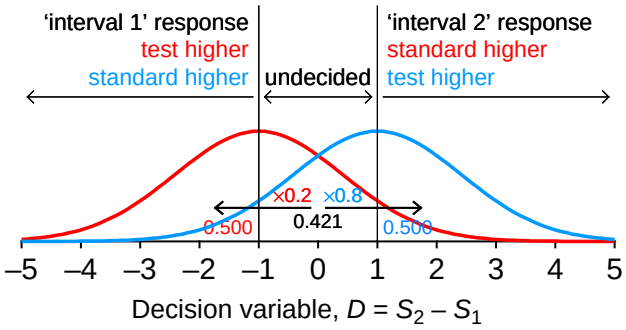
Decision space; test first, test second



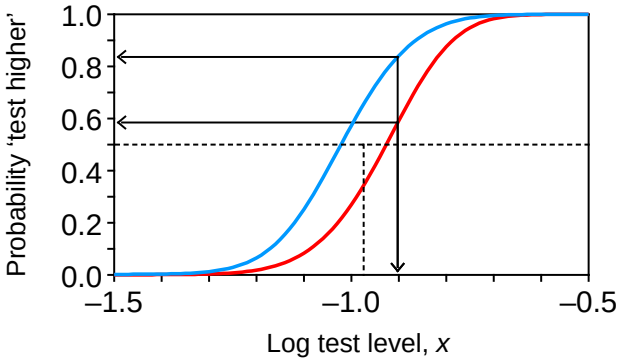
Psychometric functions



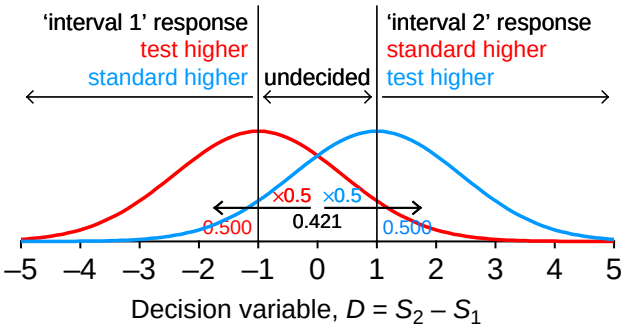
Decision space; test first, test second



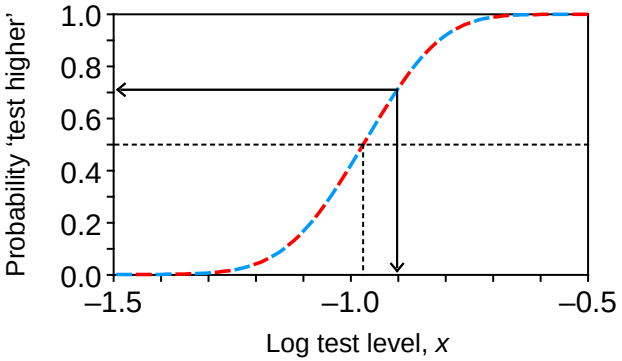
Psychometric functions



Decision space; test first, test second



Psychometric functions



How indecision explains order effects in binary tasks: Experimental test

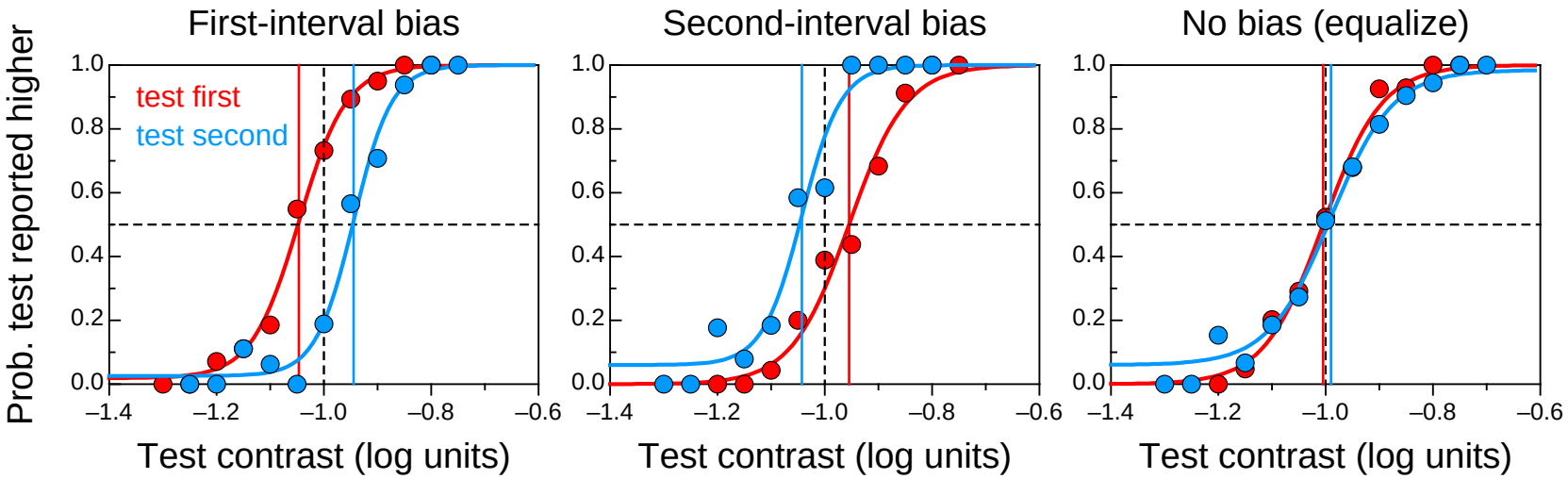
Alcalá-Quintana, R. & García-Pérez, M. A. (2011). A model for the time-order error in contrast discrimination. *Quarterly Journal of Experimental Psychology*, *64*, 1221–1248

sample

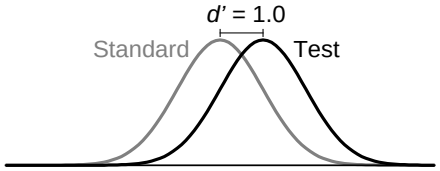
test

Which one has higher contrast?
But:

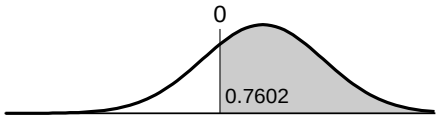
- respond "first" when undecided
- respond "second" when undecided
- equalize "first" and "second" when undecided



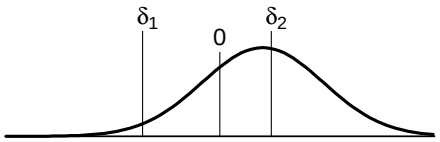
How indecision affects adaptive threshold estimates in binary tasks



Perceived magnitude, S



Decision variable, $D = S_t - S_s$



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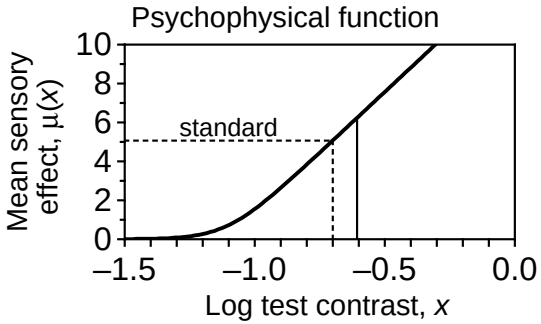
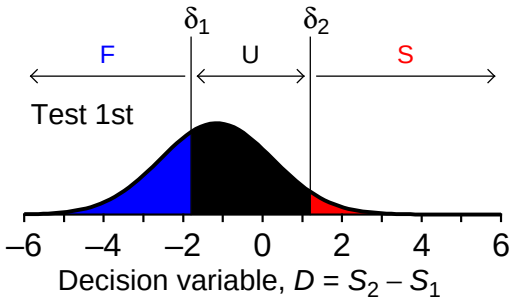
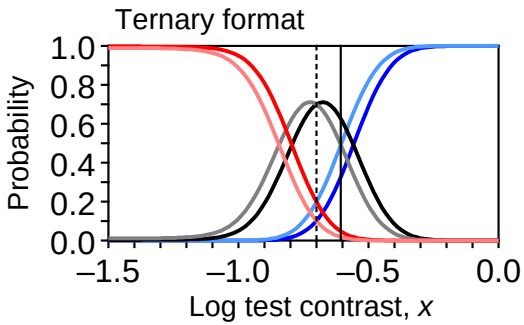
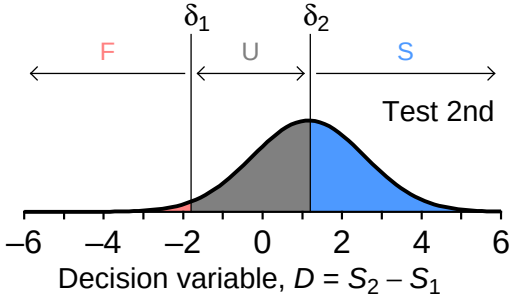
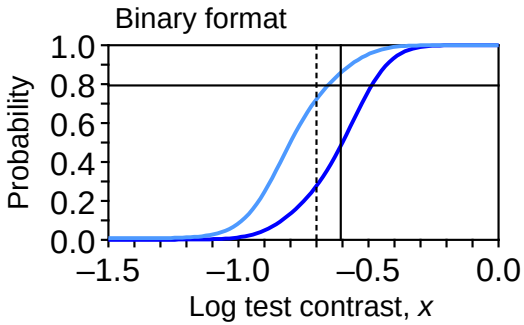


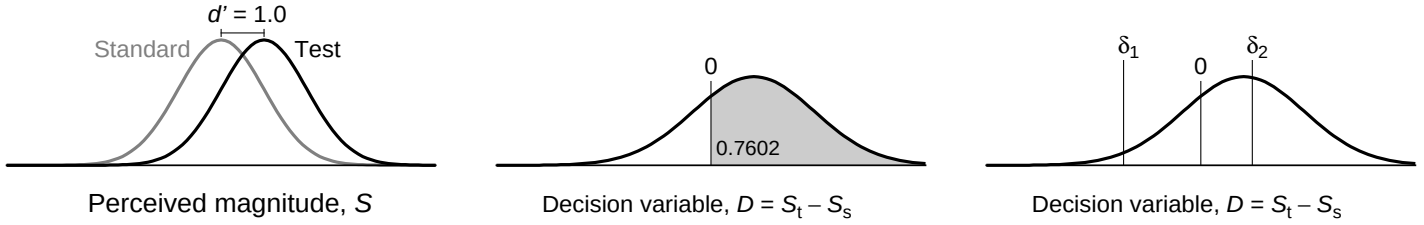


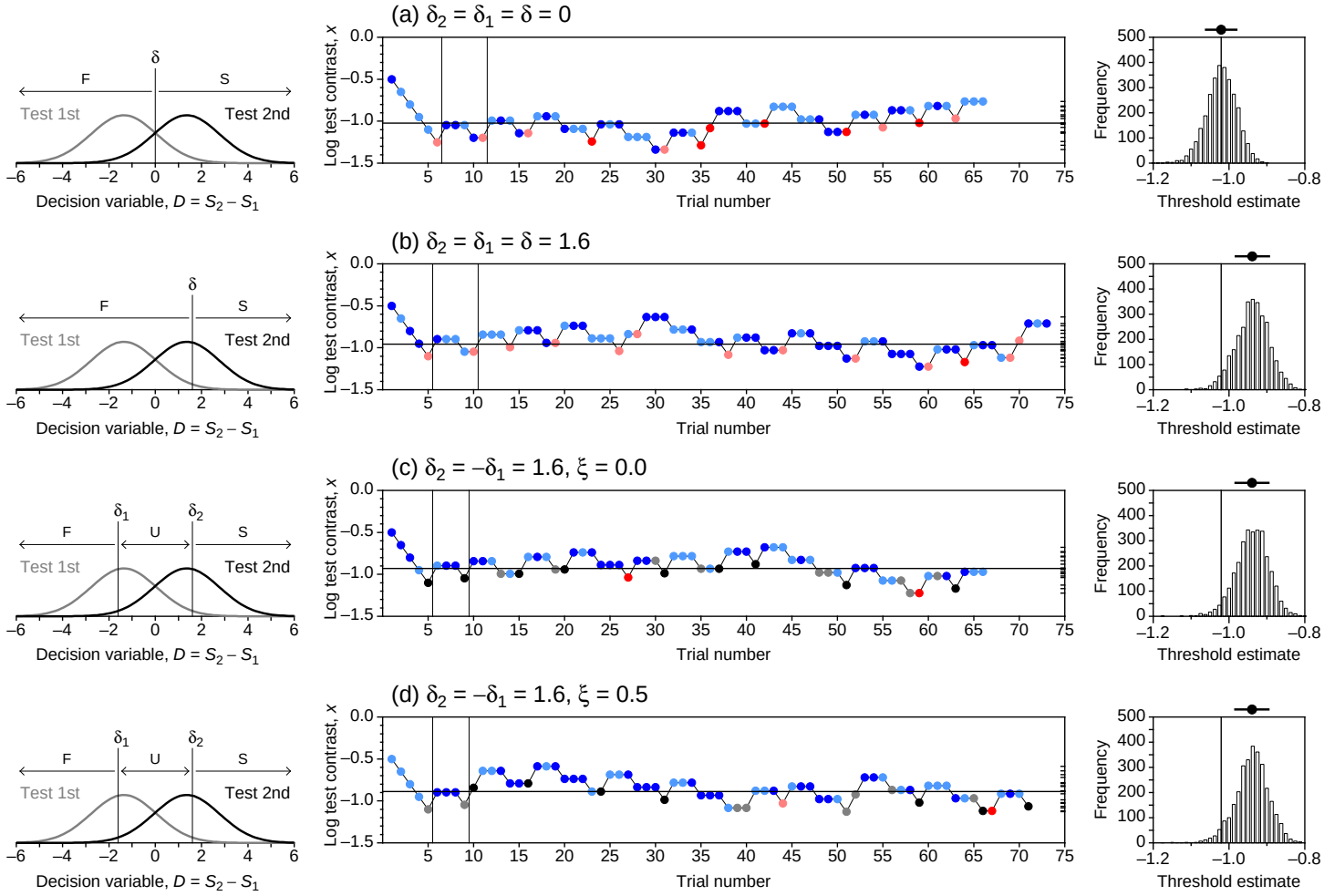






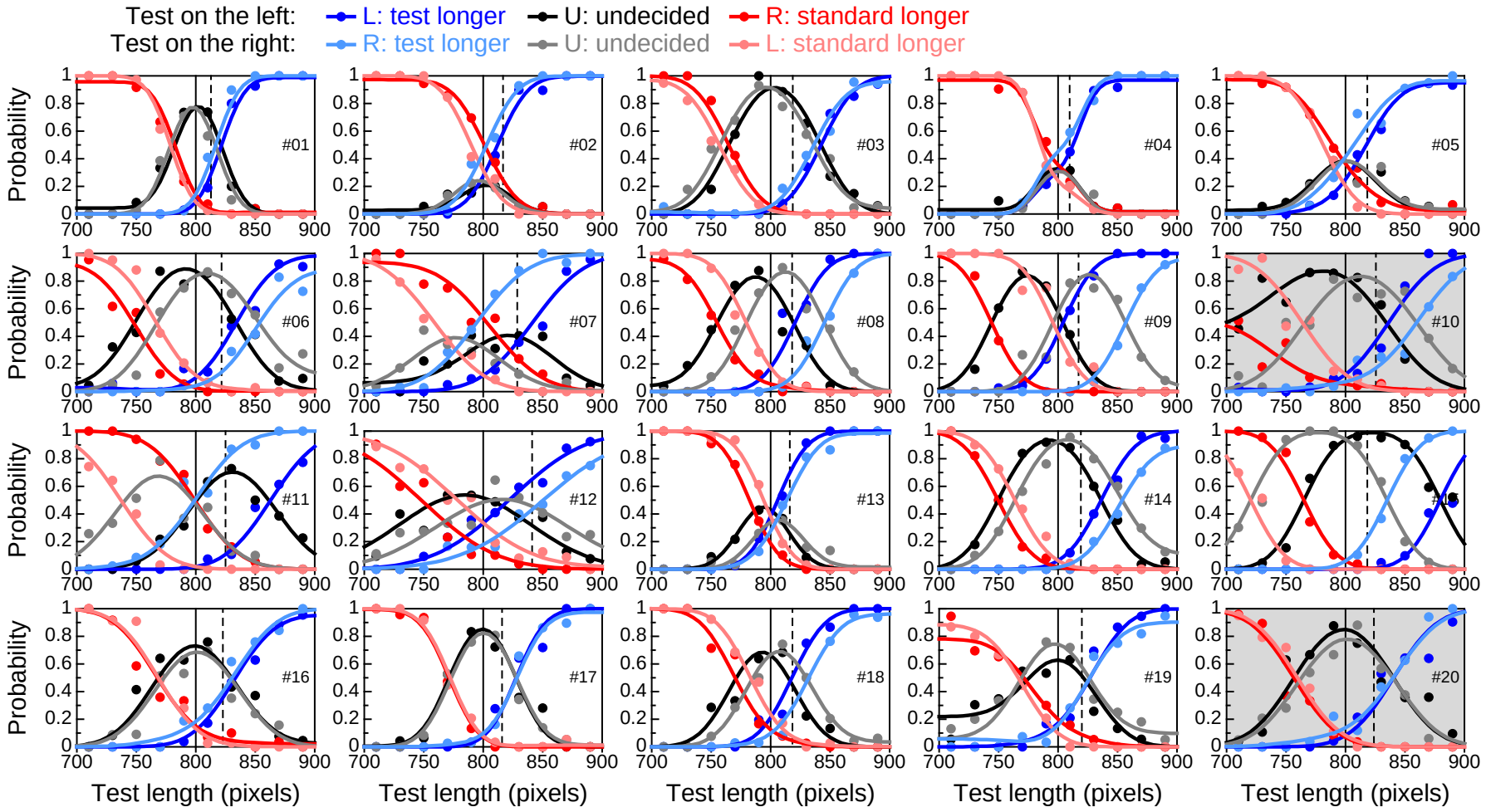
How indecision affects adaptive threshold estimates in binary tasks





How indecision affects adaptive threshold estimates in binary tasks

García-Pérez, M. A. & Alcalá-Quintana, R. (2020). Order effects in two-alternative forced-choice tasks invalidate adaptive threshold estimates. *Behavior Research Methods*, *52*, 2168–2187



How indecision affects adaptive threshold estimates in binary tasks

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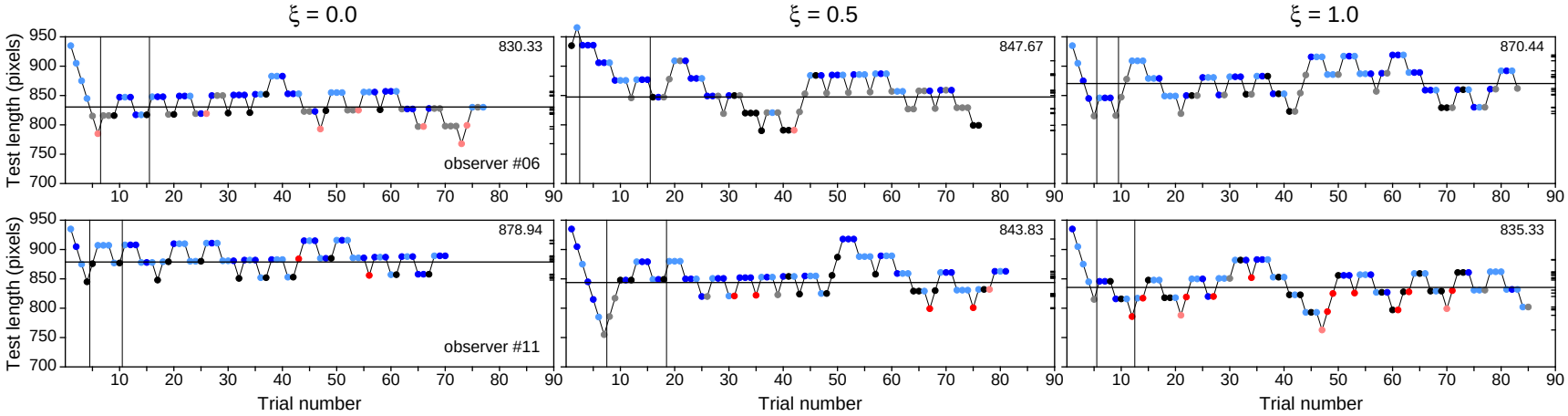
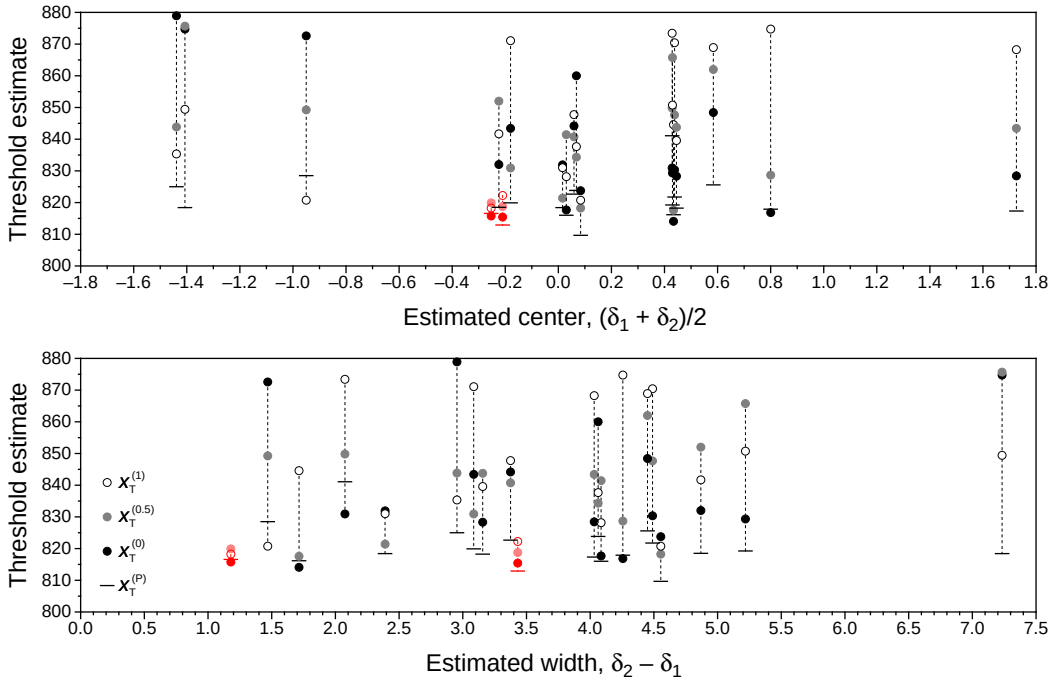




Conclusions

1 – Single-presentation methods are **useless**: They confound perceptual effects and decisional bias in a way that the data are uninterpretable

2 – Dual-presentation methods are **misleading** when administered with the conventional binary response format (which one is higher?) followed by aggregation of data across presentation orders or positions: Decisional bias still affects the form of the observed psychometric function

3 – Dual-presentation methods are **dependable** when administered with the three-response format (or the same–different format) followed by a joint analysis of data separated by presentation order or position: This separates out perceptual and decisional influences

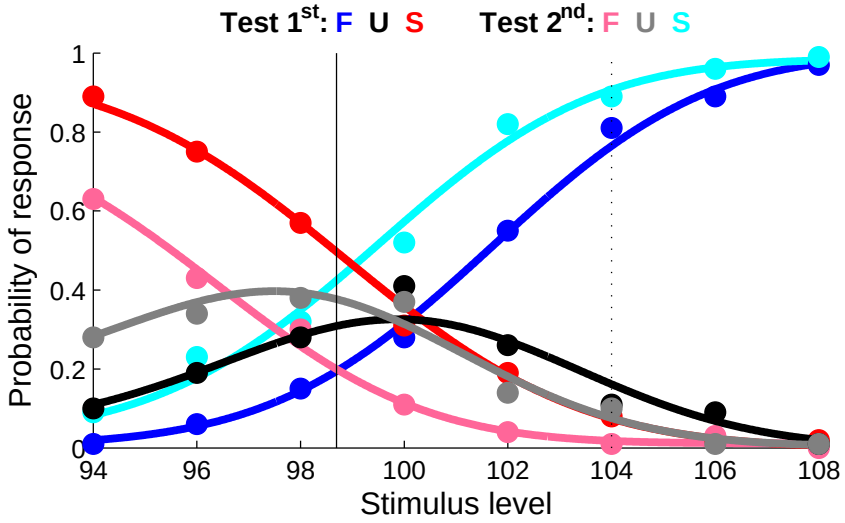
4 – Adaptive methods for quick threshold estimation are **useless**

How difficult is this to do?

García-Pérez, M. A. & Alcalá-Quintana, R. (2017). The indecision model of psychophysical performance in dual-presentation tasks: Parameter estimation and comparative analysis of response formats. *Frontiers in Psychology*, *8*:1142

Conclusions

1 – Single-presentatic



perceptual effects and decisional bias in

2 – Dual-presentation

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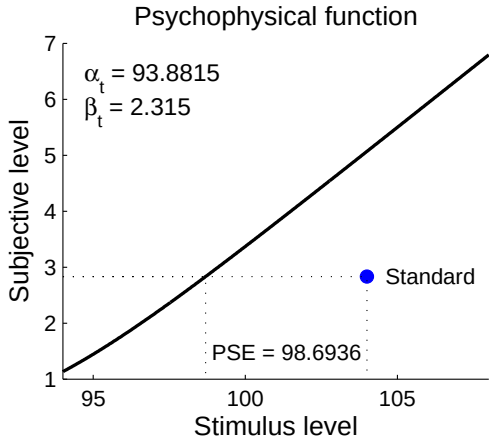

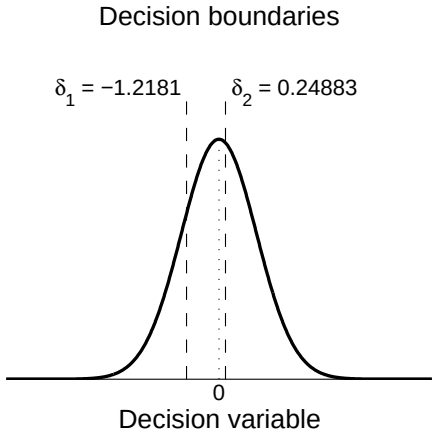

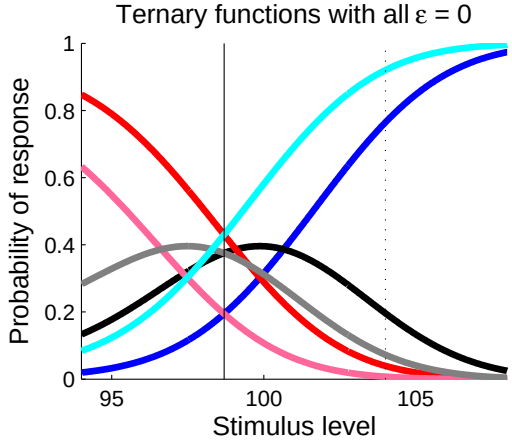

García-Pérez, M. A. & Alcalá-Quintana, R. (2017). The indecision model of psychophysical performance in dual-presentation tasks: Parameter estimation and comparative analysis of response formats. *Frontiers in Psychology*, *8*:1142

Recent publications on this topic

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García-Pérez, M. A. & Alcalá-Quintana, R. (2019). The do's and don'ts of psychophysical methods for interpretability of psychometric functions and their descriptors. *Spanish Journal of Psychology*, *22*, e56

García-Pérez, M. A. & Alcalá-Quintana, R. (2020). Order effects in two-alternative forced-choice tasks invalidate adaptive threshold estimates. *Behavior Research Methods*, *52*, 2168–2187