Causal Inference Modulates Audiovisual Temporal Recalibration

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Introduction

• Audiovisual temporal recalibration: Exposure to a constant audiovisual lag alters perceived asynchrony[1,2]

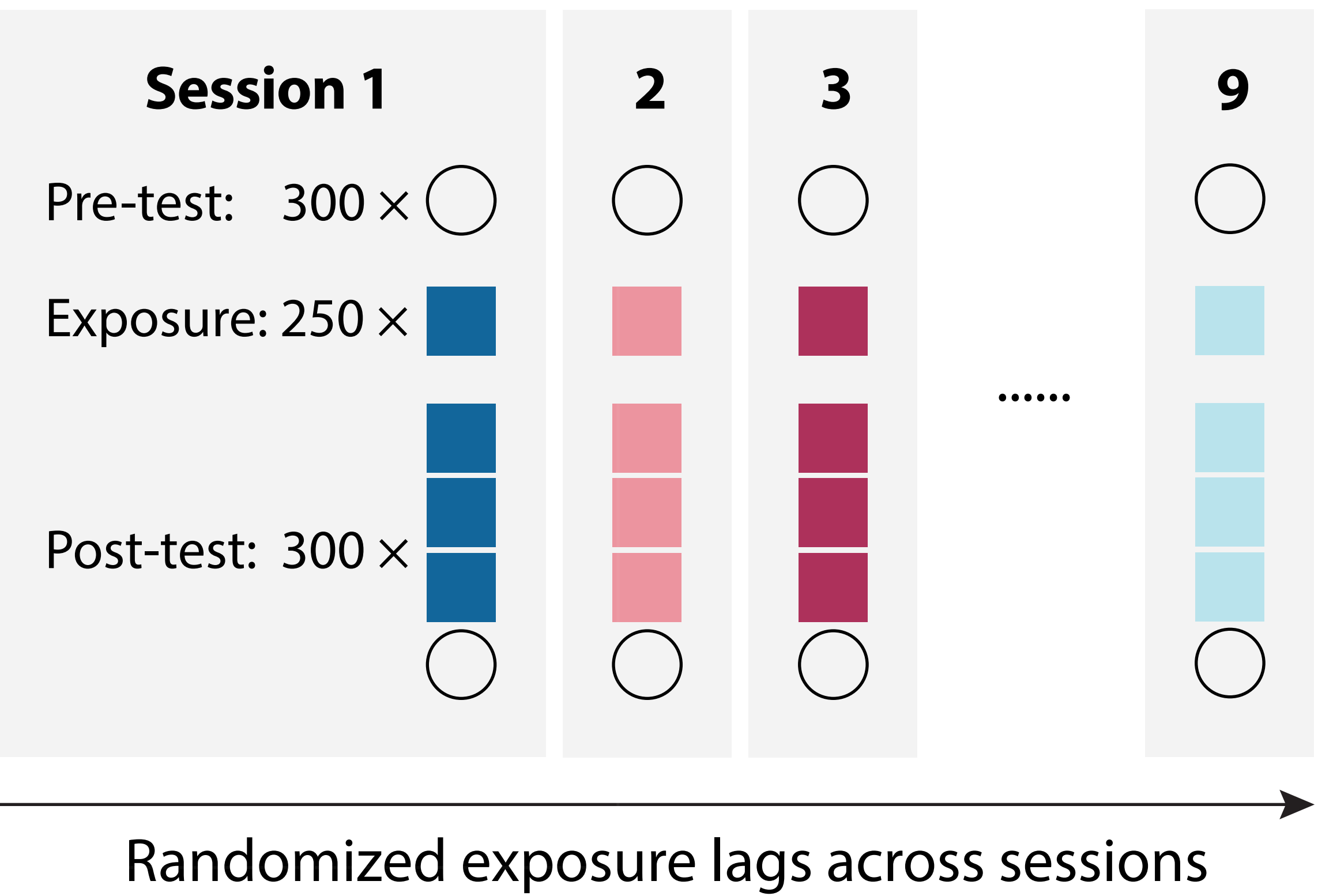• Causal inference: Inferring the probability of a common cause (C=1) vs. separate causes (C=2)[3,4]
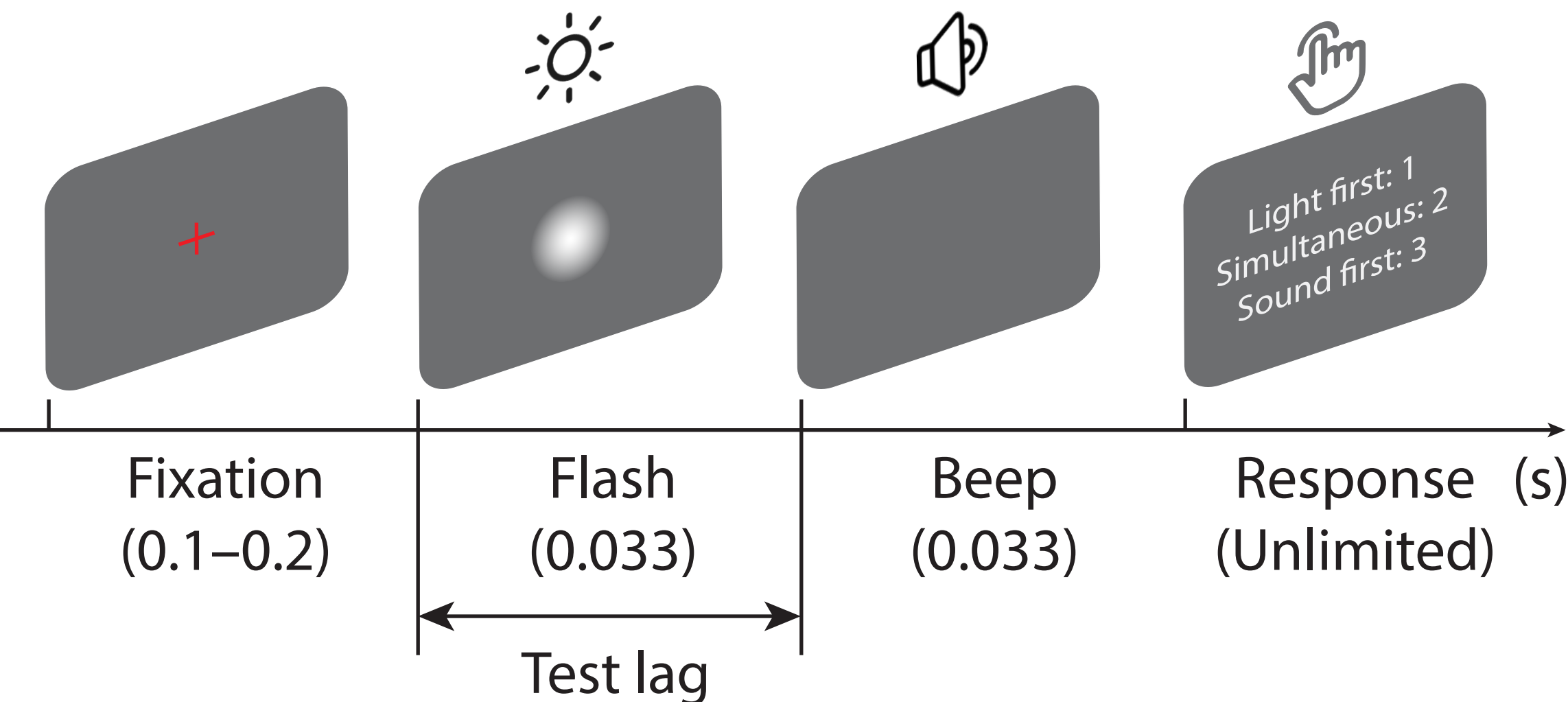
C=1

C=2
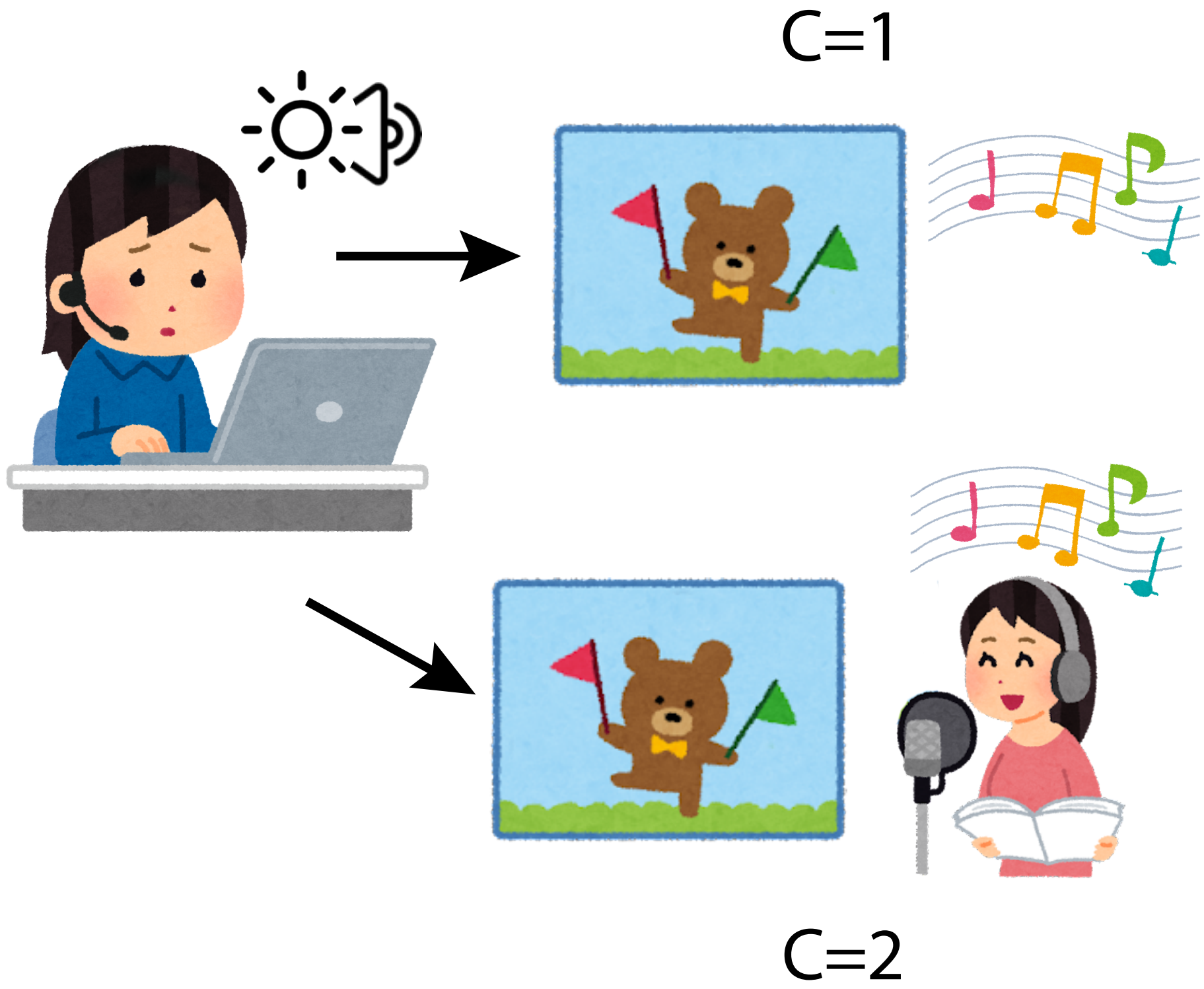
Research question

Does causal inference impact recalibration of the lag between sound and light?

Methods

Schedule

	Session 1	2	3	...	9
Pre-test:	300 × ◯	◯	◯		◯
Exposure:	250 × ■	■	■		■
Post-test:	300 × ■	■	■		◯
	◯	◯	◯		◯

Randomized exposure lags across sessions

◯ Pre/post: Temporal-order judgement

Lag varies across trials

Fixation (0.1–0.2)   Flash (0.033)   Beep (0.033)   Response (s) (Unlimited)

Light first: 1
Simultaneous: 2
Sound first: 3

Test lag
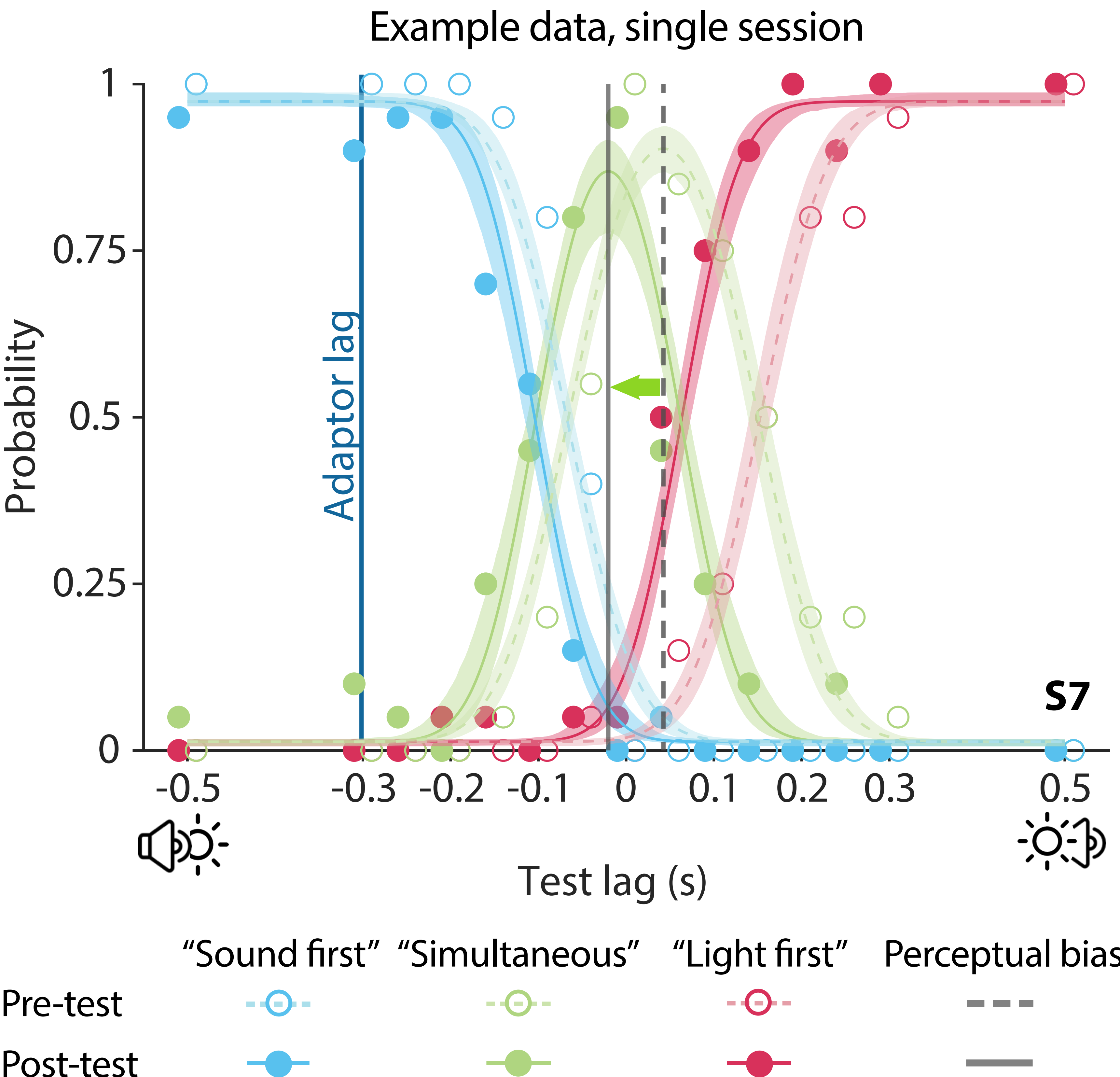
Goal: Measure the perceptual audiovisual biases before and after exposure to a constant lag

☐ Exposure

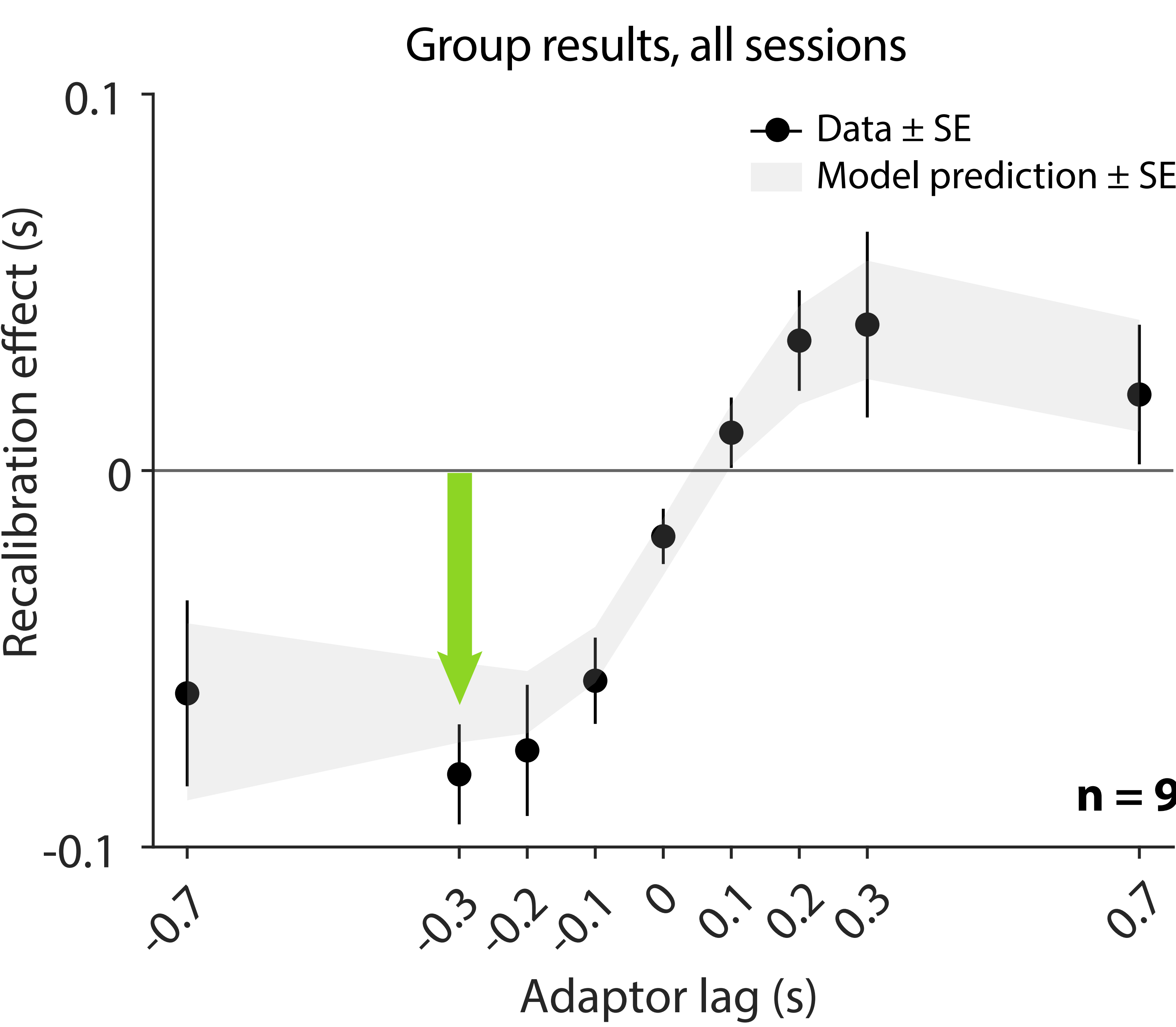Lag is constant across trials

Trials   Adaptor lag   Time(s)
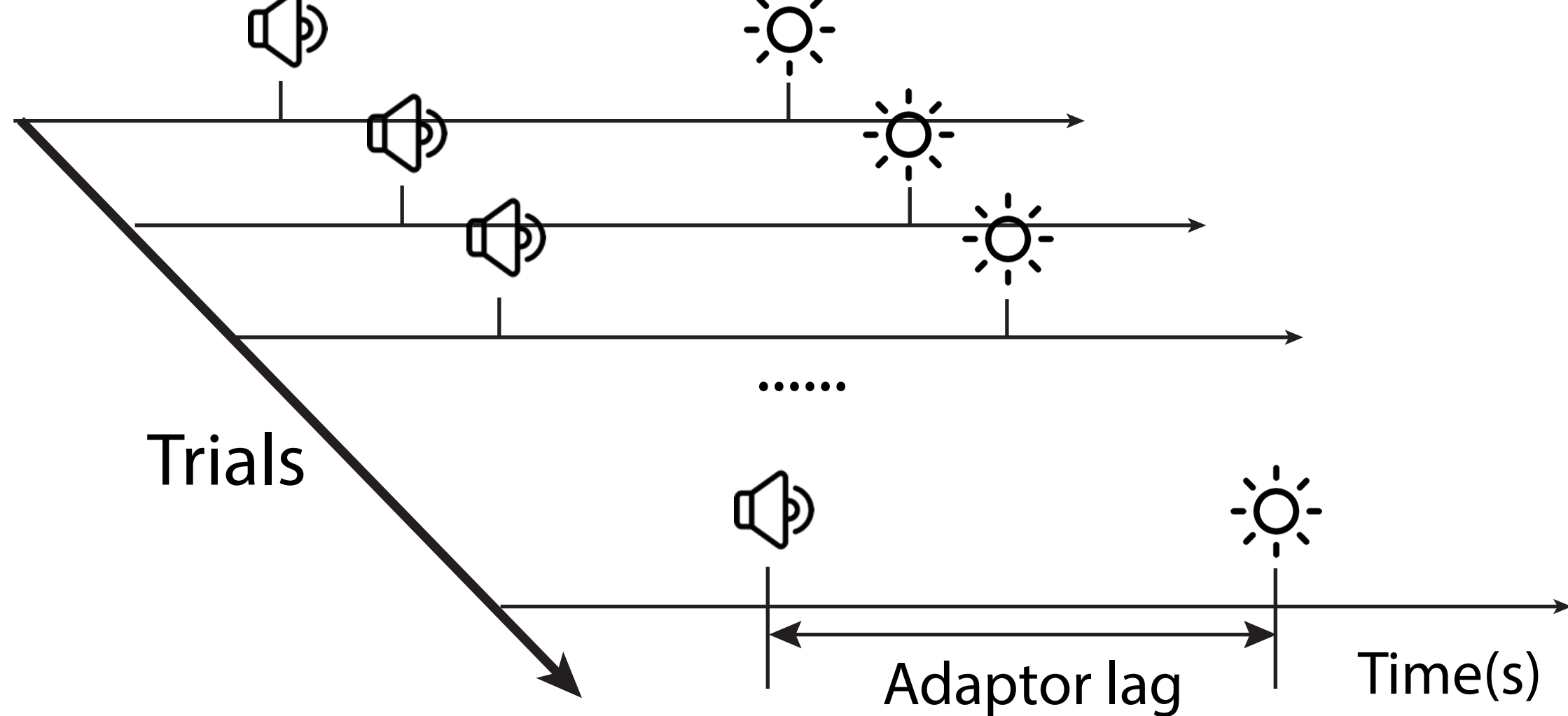
Goal: Evoke audiovisual recalibration within a session
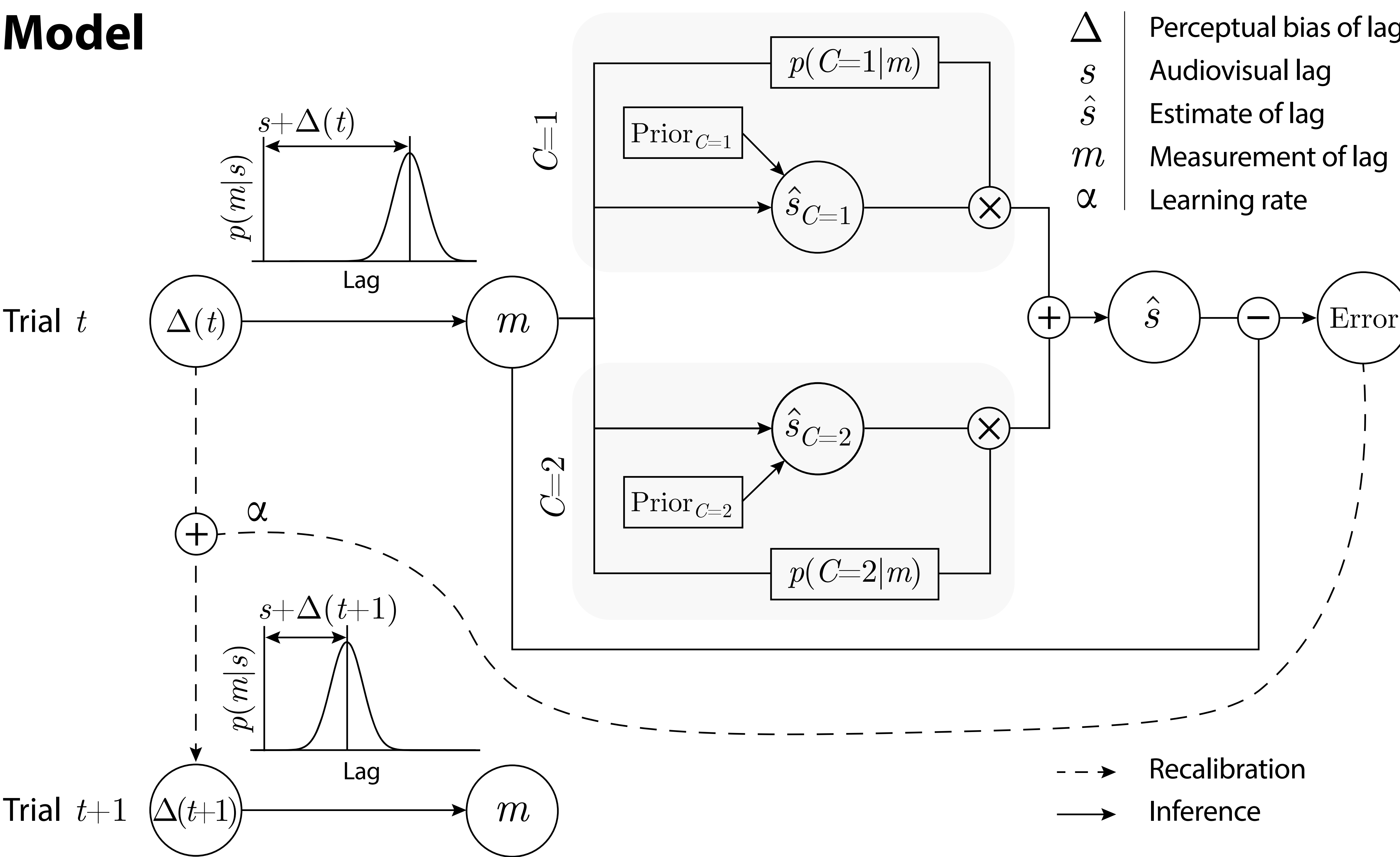**Task:** Ensures observer's attention to both modalities

Psychometric functions

Example data, single session

Probability

Adaptor lag

S7

Test lag (s)

"Sound first"   "Simultaneous"   "Light first"   Perceptual bias

Pre-test
Post-test

Recalibration results

Group results, all sessions

Recalibration effect (s)

— Data ± SE
▨ Model prediction ± SE

n = 9

Adaptor lag (s)

Causal-inference model[5,6] captures decreased magnitude of recalibration at large adaptor lags.

Model

Δ — Perceptual bias of lag
s — Audiovisual lag
$\hat{s}$ — Estimate of lag
m — Measurement of lag
α — Learning rate

$s+\Delta(t)$
$p(m|s)$
Lag

Trial t $\Delta(t)$ m

$p(C{=}1|m)$
$\text{Prior}_{C=1}$ $\hat{s}_{C=1}$ ⊗
$C=1$

$\text{Prior}_{C=2}$ $\hat{s}_{C=2}$ ⊗
$C=2$
$p(C{=}2|m)$

$+$ $\hat{s}$ $-$ Error

α
$+$

$s+\Delta(t+1)$
$p(m|s)$
Lag

Trial $t+1$ $\Delta(t+1)$ m

- - - Recalibration
—— Inference

Conclusion

Cross-modal temporal recalibration relies on observers' multisensory estimates, which in turn are guided by causal inference.

[1]Fujisaki et al., 2004
[2]Vroomen et al., 2004
[3]Körding et al., 2007
[4]Sato, Toyoizumi, & Aihara, 2007
[5]Hong, Badde, & Landy, 2021
[6]Badde, Navarro, & Landy, 2020
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