Modeling the effects of attention on causal inference in multisensory perception

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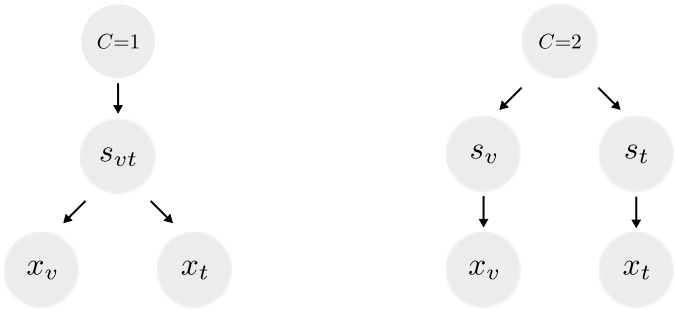
Causal Inference for visual-tactile localization and recalibration



Körding et al., 2007

Attention toward a modality: Ventriloquism and its aftereffect

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Attention toward a modality: Ventriloquism and its aftereffect

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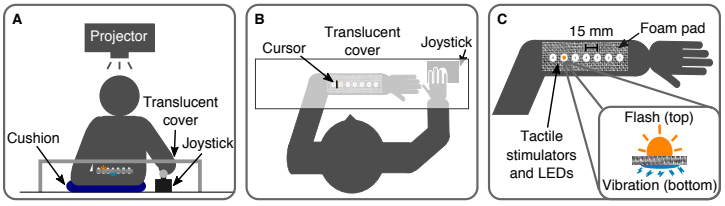
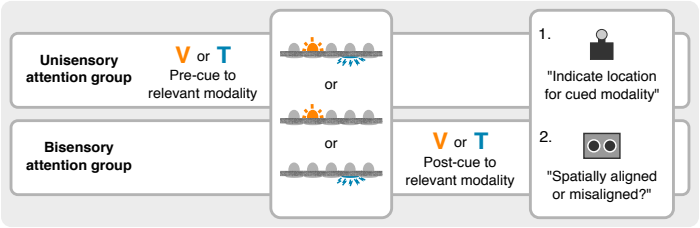
- Does modality-specific attention influence spatial visual-tactile integration?
- Can modality-specific attention influence recalibration (the ventriloquism aftereffect)?
- Does it do so via cue reliability or causal inference?

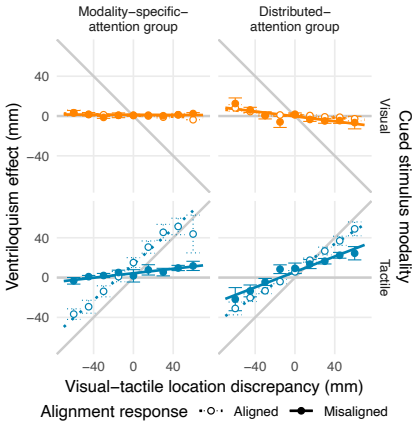
1. Ventriloquism effect: Apparatus



Ventriloquism effect: Procedure



Ventriloquism effect: Results



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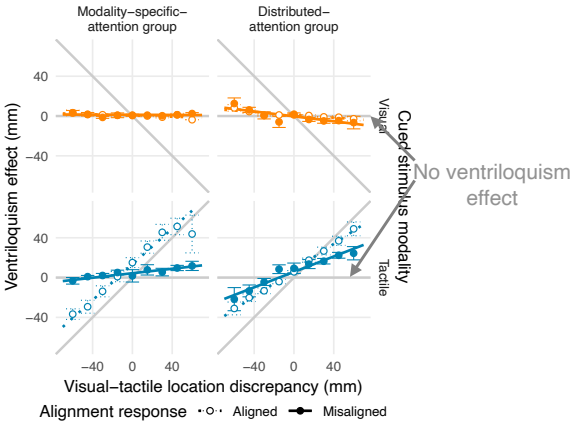

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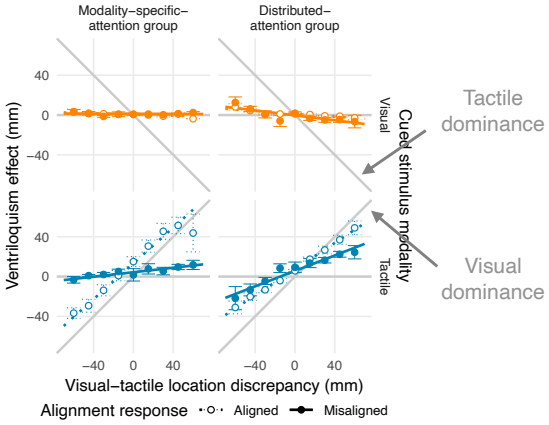

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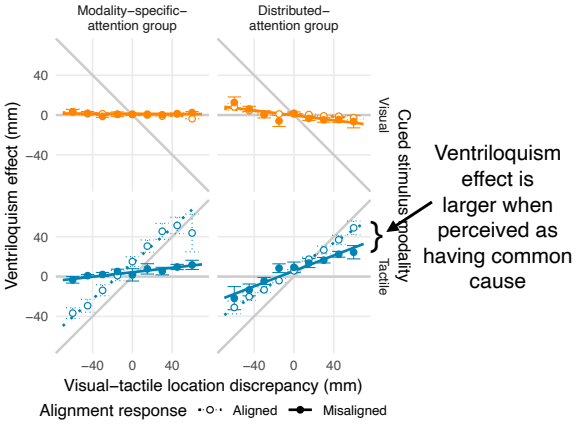

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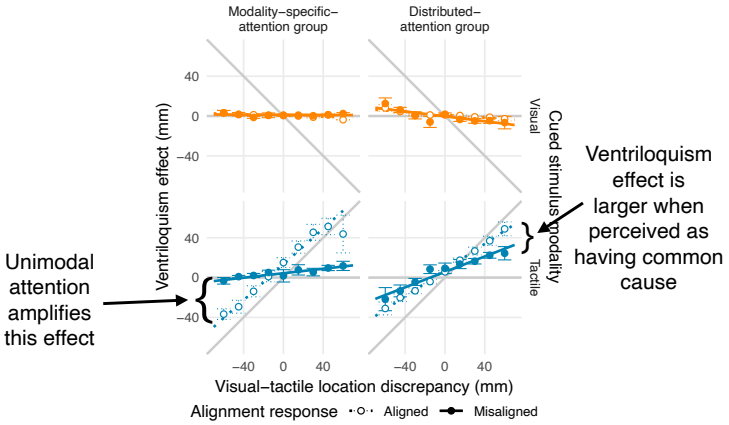

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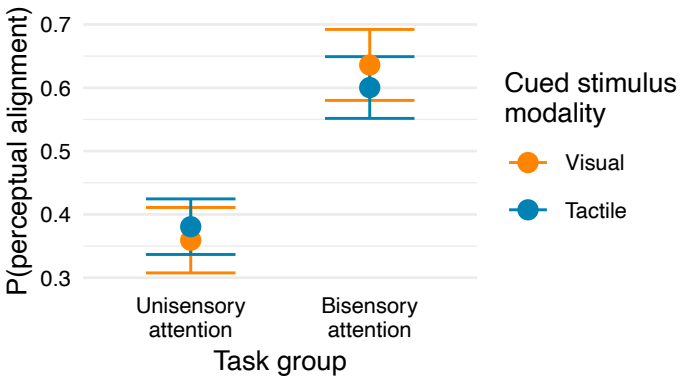
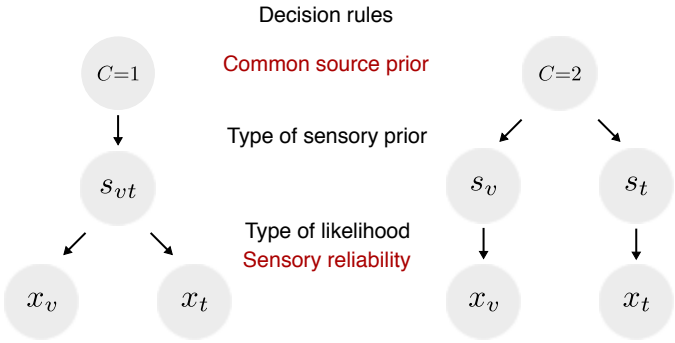


Ventriloquism effect: Conclusions

Distribution of attention across the two modalities leads to stronger ventriloquism, including

- an increase in the proportion of perceived alignment of tactile-visual stimuli
- increased tactile shifts toward the visual stimulus for stimulus pairs judged to be misaligned, while the shifts for stimuli judged to be aligned is near-maximal in both attention conditions.

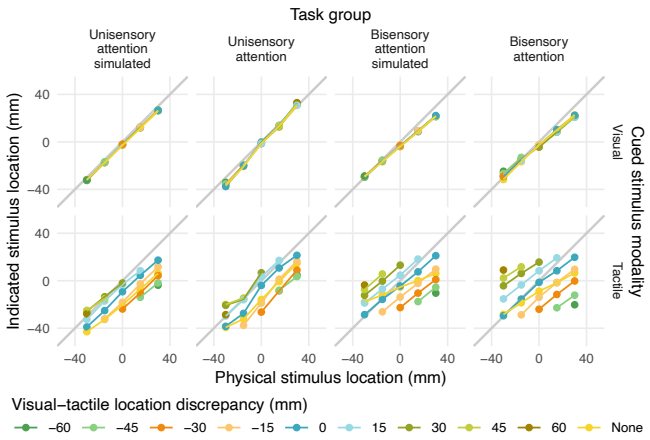
Ventriloquism effect: Models



Ventriloquism effect: Models

- The winning model (using AIC) was the same for the unisensory and bisensory attention groups
- Localization responses based on the ideal observer, but overt common-cause judgments based on a heuristic: the distance between the unisensory location estimates

Ventriloquism effect: Modeling



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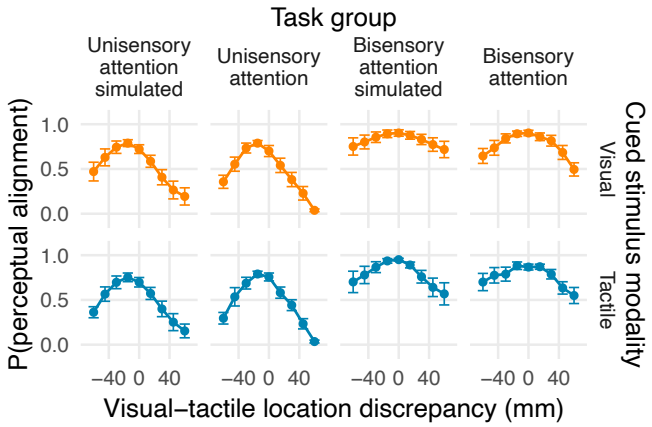
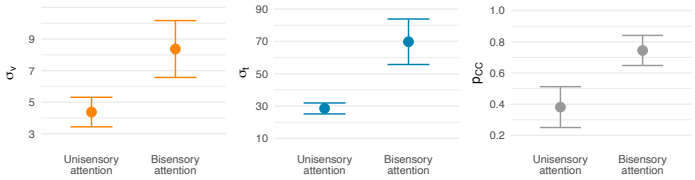


Ventriloquism effect: Modeling

The model allowed for an effect of modality-specific attention on tactile and visual variability (σ_t^2, σ_v^2) and the prior probability of a common cause (p_{CC}).



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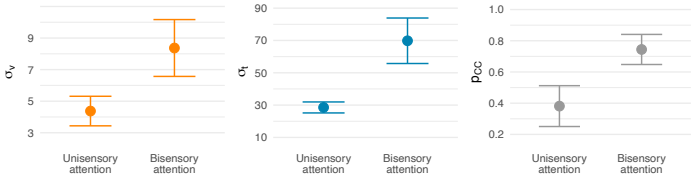
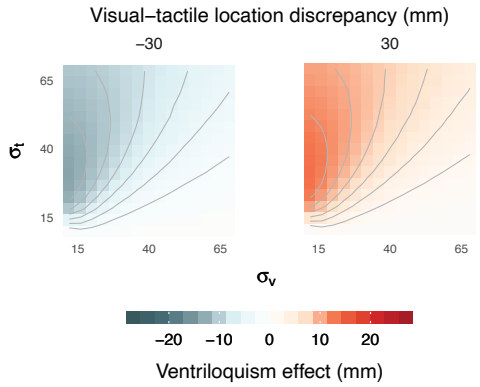


Distributed attention increases localization noise (e.g., due to limited capacity) and increases the "prior" probability of a common cause.

Ventriloquism model simulations: Tactile shifts



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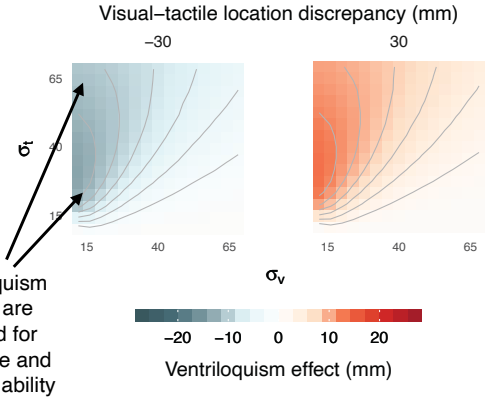

Ventriloquism effects are reduced for both large and small variability

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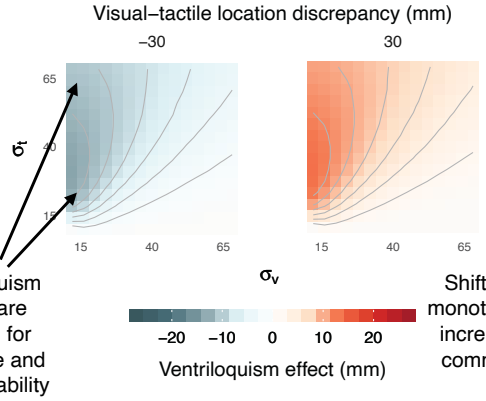
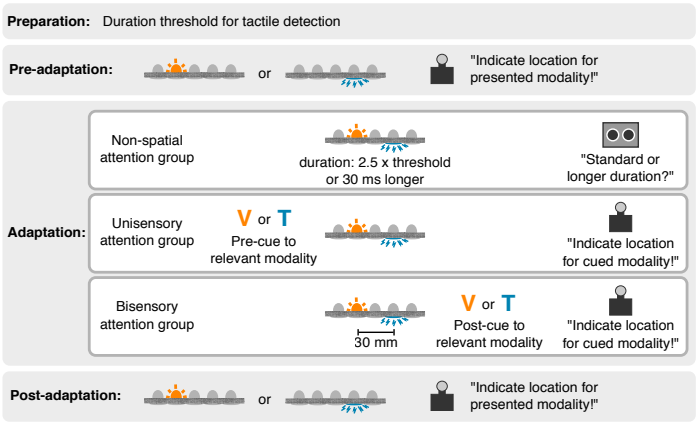


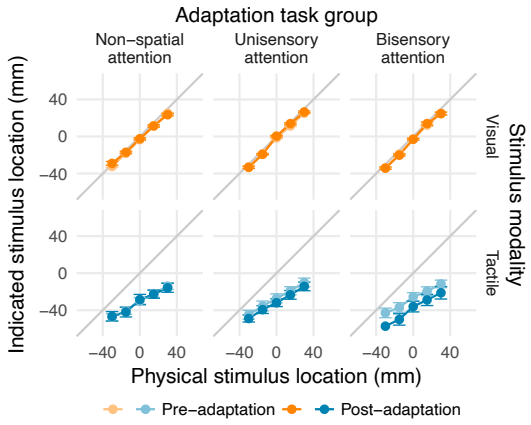
Ventriloquism effects are reduced for both large and small variability

Shifts increase monotonically with increases in the common-cause prior

2. Ventriloquism aftereffect: Procedure



Ventriloquism aftereffect: Results



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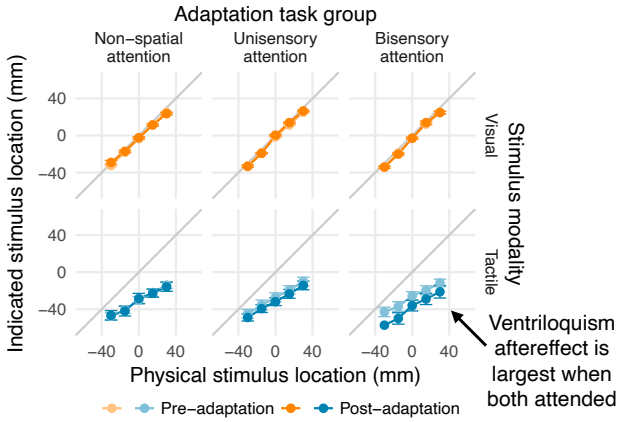

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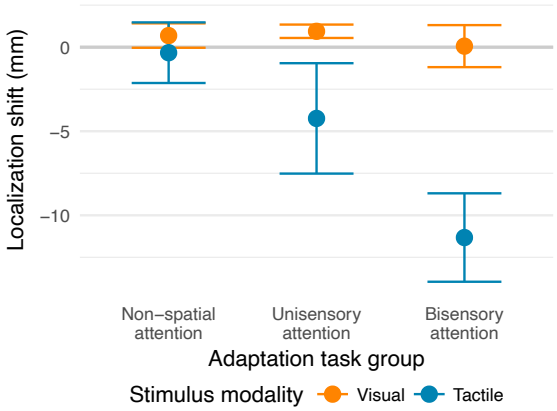


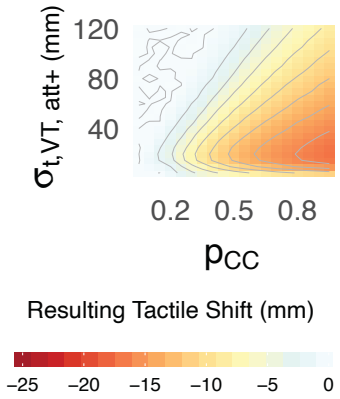
Ventriloquism aftereffect: Conclusions

- Recalibration of touch significant only when both modalities' locations are attended during the adaptation phase
- Perhaps this is due to the degree of integration during the adaptation phase, which is influenced by cue reliability and the common-cause prior
- No recalibration of vision

Ventriloquism aftereffect: Models

- On each trial, likelihood shifts are updated based on the discrepancy between cue measurements and estimates
- Cue estimates depend on measurements, priors, and the estimated probability of a common cause
- Updates can occur
  - Always
  - Only when the probability of a common cause > 0.5
  - Always, but modulated by the probability of a common cause

Ventriloquist aftereffect: Modeling



Ventriloquism aftereffect: Model results

- All three models predict greater recalibration with larger p_{CC}
- The dependence of recalibration on the reliability of the tactile stimulus is non-monotonic: Relative to high tactile reliability:
  - reducing tactile reliability leads to greater tactile recalibration
  - but when reliability is low enough, reducing it further leads to *less* recalibration

Ventriloquism aftereffect: Model results

- All three models predict greater recalibration in the bisensory attention condition
- However, only the second model, in which updates only occur if the estimated probability of a common cause is high, predicts an effect large enough to accord with the observed results

Conclusions

Attention to a cue contributes in two ways:

- Attention toward a single modality increases its reliability, however, this might increase or decrease ventriloquism effects or aftereffects, depending on the level of reliability
- However, the strongest contribution of distributing attention across modalities is surprising: it strengthens the “prior” of the two cues as having a common cause, thus “priors” aren’t really prior, but depend on context/ state variables

Badde, S., Navarro, K. T. & Landy, M. S. (2020). *Cognition*, *197*, 104170 NIH EY08266