The Neural Basis of Visuotactile Multisensory Integration

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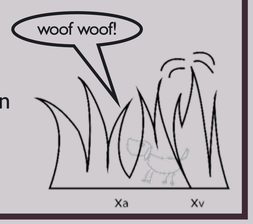
Main Questions

I. ***How does the brain integrate separate streams of sensory input to create a unified representation of what we perceive and experience?***
II. ***Where does the brain represent multisensory integration?***
III. ***What are the computational parameters that govern multisensory integration?***

Background & Theory

Multisensory Integration

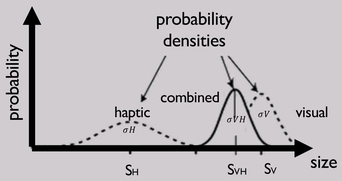
- *The ability of the brain to integrate multiple streams of sensory input into a single percept or representation*
- Studied across various sensory modalities such as vision, touch, proprioception, motor, and auditory
- Studied across various processes such as localization or detection
- Factors that can influence multisensory integration
  - Reliability of sensory input
  - Embodiment
  - External noise



Bayesian Causal Inference

Model-Based Cognitive Neuroscience

- Combines cognitive and mathematical psychology by explaining different behaviors or brain states with mathematical models that account for variation of multiple parameters (Palmeri et al., 2016)
- Different methods, including Bayesian causal inference (optimal integration)



$$P(Z_V, Z_H|s_V, s_H) = \frac{P(s_v s_H|Z_V, Z_H) * P(Z_V, Z_H)}{P(s_V, s_H)}$$

Bayesian Causal Inference & Multisensory Integration

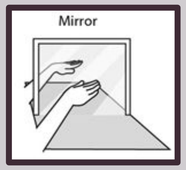
- Ex. Visual-haptic integration can be explained with optimal integration
  - Probability densities of each separate sensory input are combined to produce one probability density
- Multiple possible hypotheses about the cause of sensory inputs
- Brain chooses one most likely hypothesis to generate perception
- Calculate probability of perception (*posterior probability*) given the probability of sensory inputs and our knowledge about the world (*prior probability*)
  - Z_V, Z_H are our knowledge about the world (visual and haptic)
  - s_V, s_H are sensory inputs (visual and haptic)

Previous Literature

Behavioral

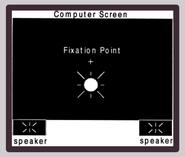
Mirror Box Experiments

- Congruent movement results in multisensory integration, where hand in the mirror feels like their own hand (Liu & Medina, 2017)



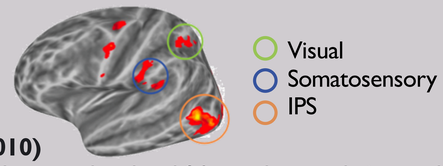
Sound-Induced Flash Illusion

- A flash of light simultaneously played with two beeps results in illusion of seeing two flashes of light (Shams, L., Kamitani, Y., & Shimojo, S. 2002)



Neuroimaging

There is behavioral evidence that the brain combines sensory inputs (see above); Can we find neural evidence for these systems?

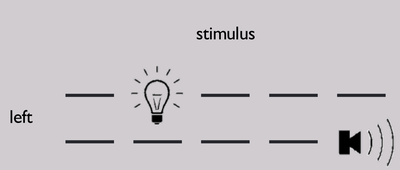


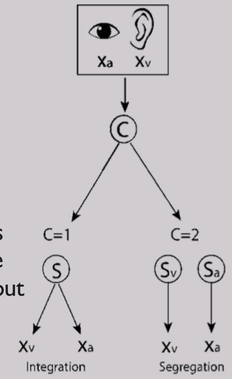
Beauchamp et al. (2010)

- Subjects viewed touches on a hand and felt touches on their own hand
- Wanted to measure connection strengths between brain regions associated with different modalities (visual + tactile)
- Reliability was manipulated to measure changes in connection strengths
- Found activation in lateral occipital cortex (LOC), somatosensory areas in inferior parietal lobe (IPL), and intraparietal sulcus (IPS)
- When visual stimuli was reliable, strength between visual area and IPS was high, but decreased when visual stimuli was unreliable (same for somatosensory stimuli)

Model-Based

Knowing there is behavioral and neural evidence for multisensory integration, what are the exact computational parameters that govern this?





Kording et al. (2007)

- Subjects asked to localize visual & auditory stimulus
- Human has to make choice between whether there are one or two causes when faced with sensory input
- Formed Bayesian model that predicted audiovisual integration in a localization task

Our Study

Objective

- Fit Bayesian model to behavioral + fMRI data from detection task
- Use model to predict neural correlates of multisensory integration
- Test whether model parameters change under different manipulations

Methods

- Participants watch video of hand being touched on index finger while receiving tactile stimulus

Potential Manipulations

- Reliability of the tactile stimulus: noisy versus more salient stimulus
- Hand posture: first person versus third person orientation

Dependent Variables

- Tactile Detection
- Visual Detection

Hypotheses

Behavioral

- Visual and tactile congruence of touch will result in increased detection of touch, whereas incongruence of visuotactile stimuli will result in lower detection of touch, biased towards tactile representation

Neuroimaging

- Now that we have behavioral evidence, how is multisensory integration represented in the brain?
- There are regions in the brain responsible for multisensory integration OR brain regions linked with various sensory modalities (e.g. visual or somatosensory cortex) are connected through a pathway

Model-based

- By examining the relationship between model parameters and neural activity, we can find brain regions involved in multisensory integration

References & Acknowledgments

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Principal Advisor: Dr. Jared Medina
This research was supported by the Undergraduate Research Program at University of Delaware.

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