LGBIO2060: Project 3
Group 11

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<u>Article:</u> Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature*, *415*(6870), 429–433. doi:10.1038/415429a

<u>Summary:</u>

The article presents a study on four right-handed observers with normal or corrected-to-normal vision. The authors asked how do observers decide which information modality to rely on? Or do they mix modalities, and if so, how do they weigh the respective information?
These modalities correspond to visual information and haptic information.

The article expected that individuals would produce an MLE estimate of sensory information based on a weighted average of input from each modality, and then offer quantitative fits for this model. They assumed that haptic and visual task estimates follow a gaussian with variance σ_H^2 and σ_V^2 respectively. And with the use of the maximum likelihood estimate rule, the final estimate which combines the previous two will have a variance σ_{VH}^2 that follows the equation (3).

Three separate experiments were carried out. In each of them, participants were asked to determine the height of a bar relative to a standard stimulus (higher or lower). The two first experiments are respectively visual-only and haptic-only. These are used to estimate the variances of the visual and haptic height estimates. For the visual-only experiment, they varied noise levels to obtain four conditions between 0 and 200%.
The third experiment mixed haptic and visual input and again altered the visual noise level.

Based on these experiments, the results about height judgments were remarkably close to those predicted by the MLE integration. The visual and haptic information are combined, and their estimates are weighted according to their reciprocal variance.

The final step was to understand how the nervous system calculates or learns variances associated with haptic and visual estimates. In fact, the variances are not constant and change in function of properties of the object and the situation. As for the auditory system, we would have a group of visual and haptic neurons that are each sensitive to a different range of heights. Each neuron has a preferred height but responds to other heights as well.

If the visual input clearly specifies the height, the visual neurons that prefer that height respond more fiercely than those that prefer other heights. The distribution of responses over the population of visual neurons has a well-defined peak. Assume that the distribution of haptic neurons in the population has a less well-defined peak. As with MLE integration, multiplying these two distributions provides a peak response that is closer to the visual peak than the haptic peak. If weakening the visual input spreads the response distribution of the visual neurons, then multiplying the visual and haptic distributions provides a peak closer to the haptic peak, as in MLE integration.

Questions:

1. *What is the research question?*

   How do people determine which information modality (between visual and haptic) to rely on? Or do they combine modalities (visual and haptic), and if so, how do they weigh the different information?

2. *Which model is used?*

   The maximum likelihood estimation is used to determine the ratio between visual and haptic estimates and combine them to create an estimate of the environmental property.

3. *What are the ingredients of the model? What are the hypotheses needed to use it?*

   The MLE rule asserts that adding the sensor estimates weighted by their normalized reciprocal variances is the best means of estimation (in terms of providing the lowest-variance estimate). (Equation (2)).

   They assume that the noise in each modality is Gaussian with variance s^2.
   They assume that the ratio of the visual weight to the haptic rate is the same as the ratio between the haptic and visual thresholds (PSEs).

4. *What are the limitations of this model?*

   One of the limitations of the MLE model is that it works only for adults. It provides any information about the development of the ability of visual-haptic integration during childhood.[1]
   Another limitation in this approach is that the computational weights of each sensory modality are not fixed and can be changed depending on the situation. The model provides a useful framework for comprehending the integration of visual and haptic information in the study's environment.

5. *What criticism do you have of this article? Both on the content and the form.*

   In this article, they modulate only the visual feedback. So, we only know that subjects appropriately modulate their reliance on visual information. We do not know whether participants optimally trade-off between vision and haptic feedback. It would be extremely interesting to observe if the same effect holds after injecting uncertainty into haptic feedback.

   On the form, the methods section that contains “stimuli” and “procedure” is at the end of the article. We are more used to finding it after the introduction, which makes it easier to understand and read.

[1] Aman, Joshua, Chiahao Lu and Juergen Konczak. “The integration of vision and haptic sensing: a computational and neural perspective.” (2010).