Integrating Vision and Haptics for Object Recognition

Sibel Toprak

Seminar Talk in *Intelligent Robotics*

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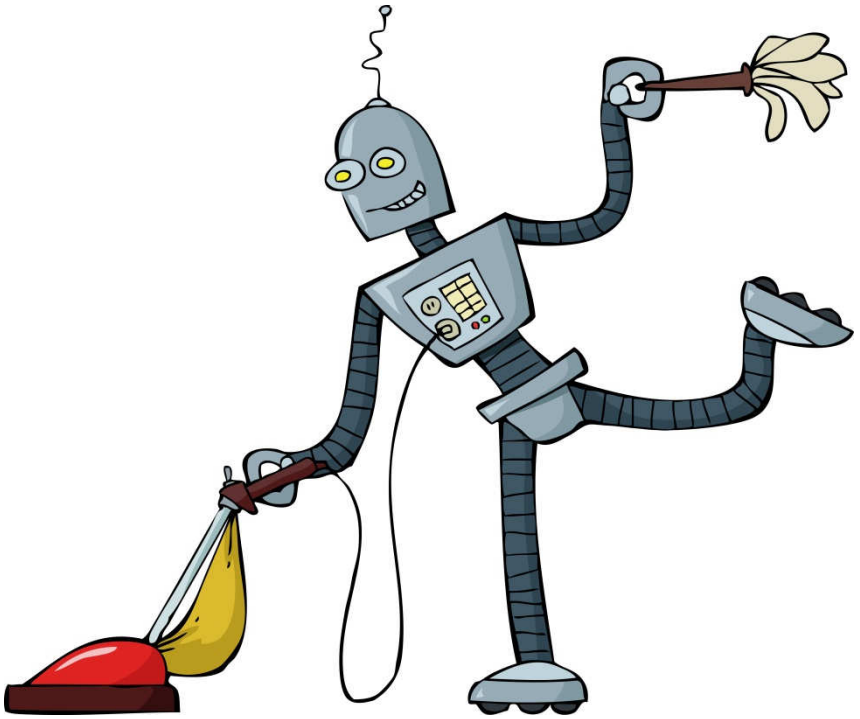
Motivation

- Robust object recognition capabilities required in most robot applications

However:

- Object recognition based on vision alone not reliable enough in most cases



http://japan-wa.de/roboter-hotel/

Visual Object Recognition

Problem 1:
Not all discerning features are visual!

"Robot, get me the full bottle!"
Which one is it?

Problem 2:
The sight is not always perfect!

Occlusions and darkness in the scene, objects that are particularly visually complex, …

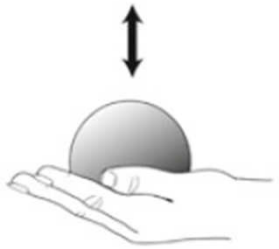
https://www.sigg.com, http://www.asdirect.fr/images/produits/p6057-2.jpg

Haptic Exploration Procedures

[Lederman and Klatzky, 2009; 1987]

Lateral Motion
(Texture)

Unsupported Holding
(Weight)

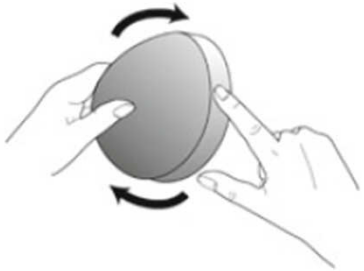


Enclosure
(Global Shape)
(Volume)

Pressure
(Hardness)

Static Contact
(Temperature)

Contour Following
(Global Shape)
(Exact Shape)



Haptic Object Recognition

Submodalities:

tactile and **kinesthetic**
(e.g. **texture** and **weight** of objects)

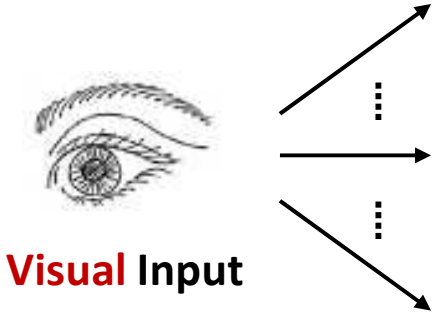
Advantages for**:**

Object Learning
More rich and distinctive characterization of objects during exploration

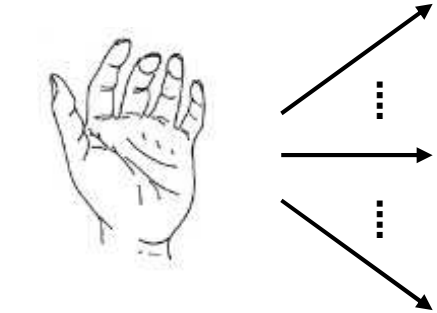
Object Manipulation
Learning how to interact with objects based on the received haptic feedback

http://de.123rf.com/photo_3716245_kleines-kind-mit-apfel--8-isoliert-auf-wei.html

Question



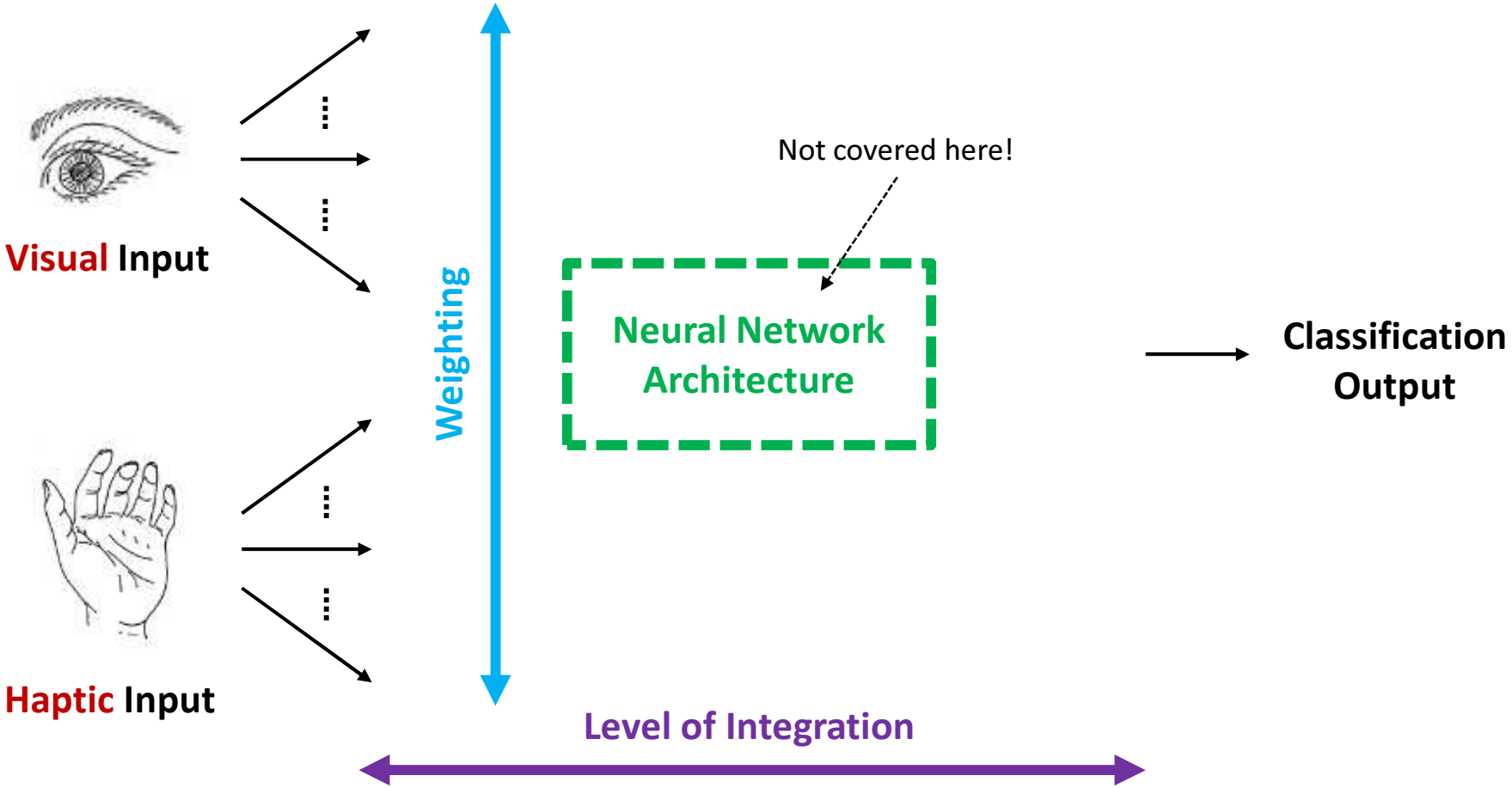
Visual Input



Haptic Input

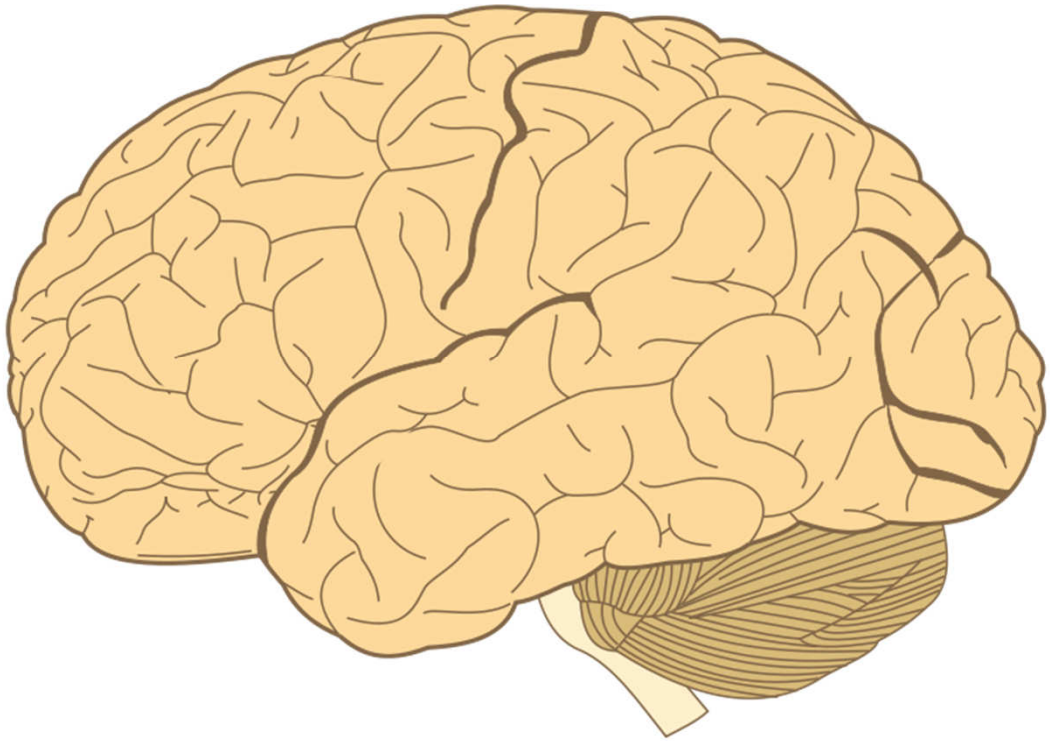
Integration Strategies? → **Classification Output**

Question


Visual Input
Haptic Input
Weighting
Not covered here!
Neural Network Architecture
Classification Output
Level of Integration

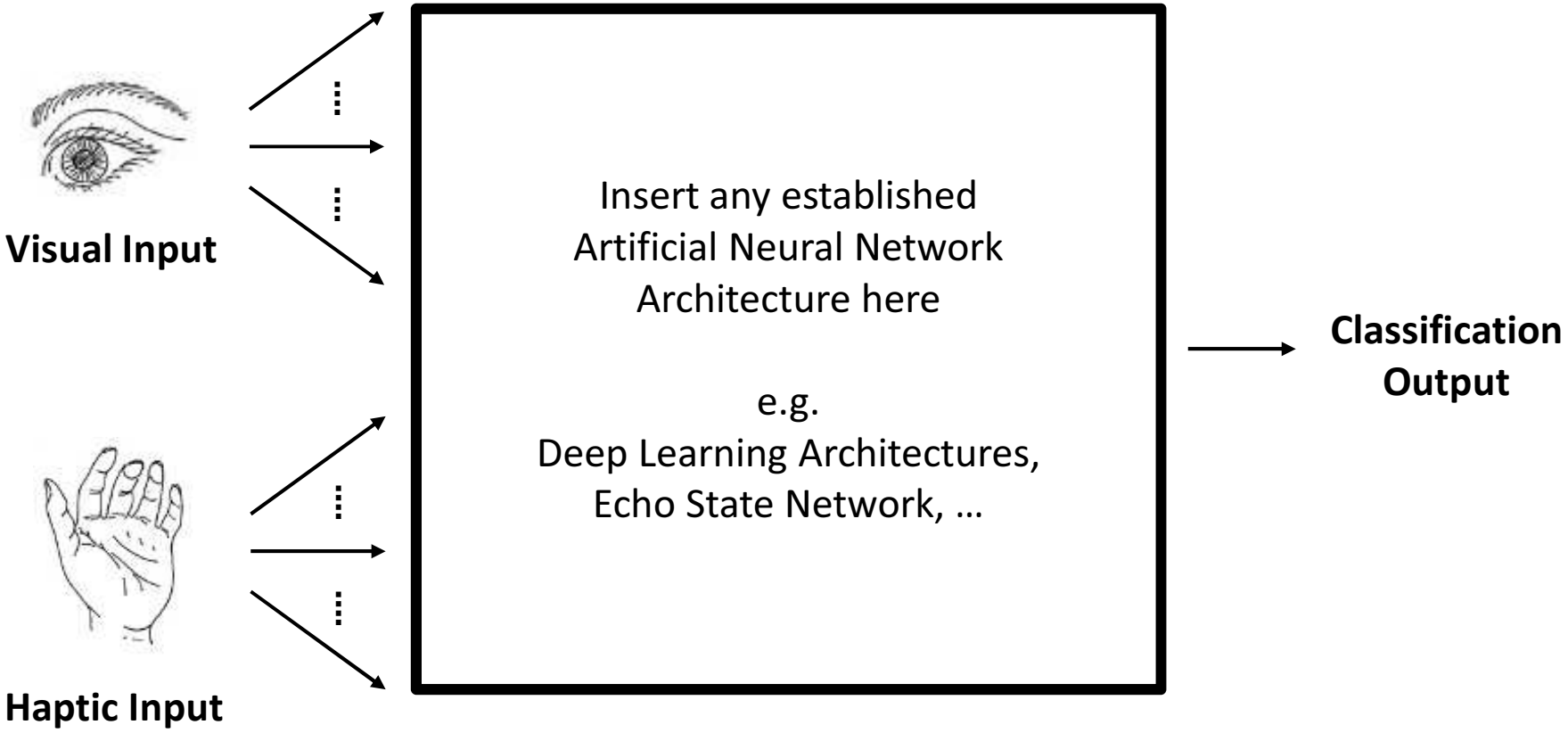
General Approach

Validate the different integration strategies using neuroscientific evidence



https://commons.wikimedia.org/wiki/File:Human-brain.SVG

Sensory-Level Integration



Issues

- **No modularity**

  ⇒Difficult reuse of processing results for other tasks

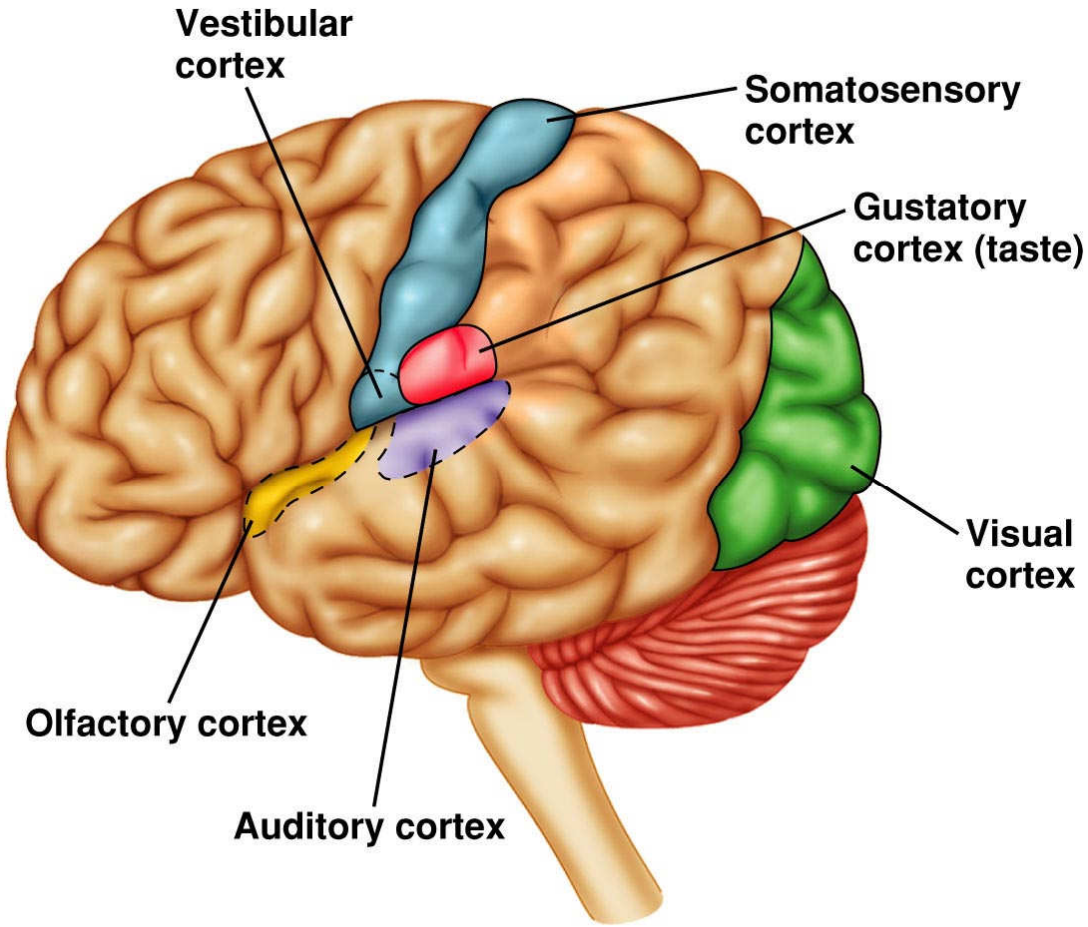
  ⇒Not much insight into what is actually learned

  ⇒Waste of computational effort

- **Neuroscientific counterevidence**

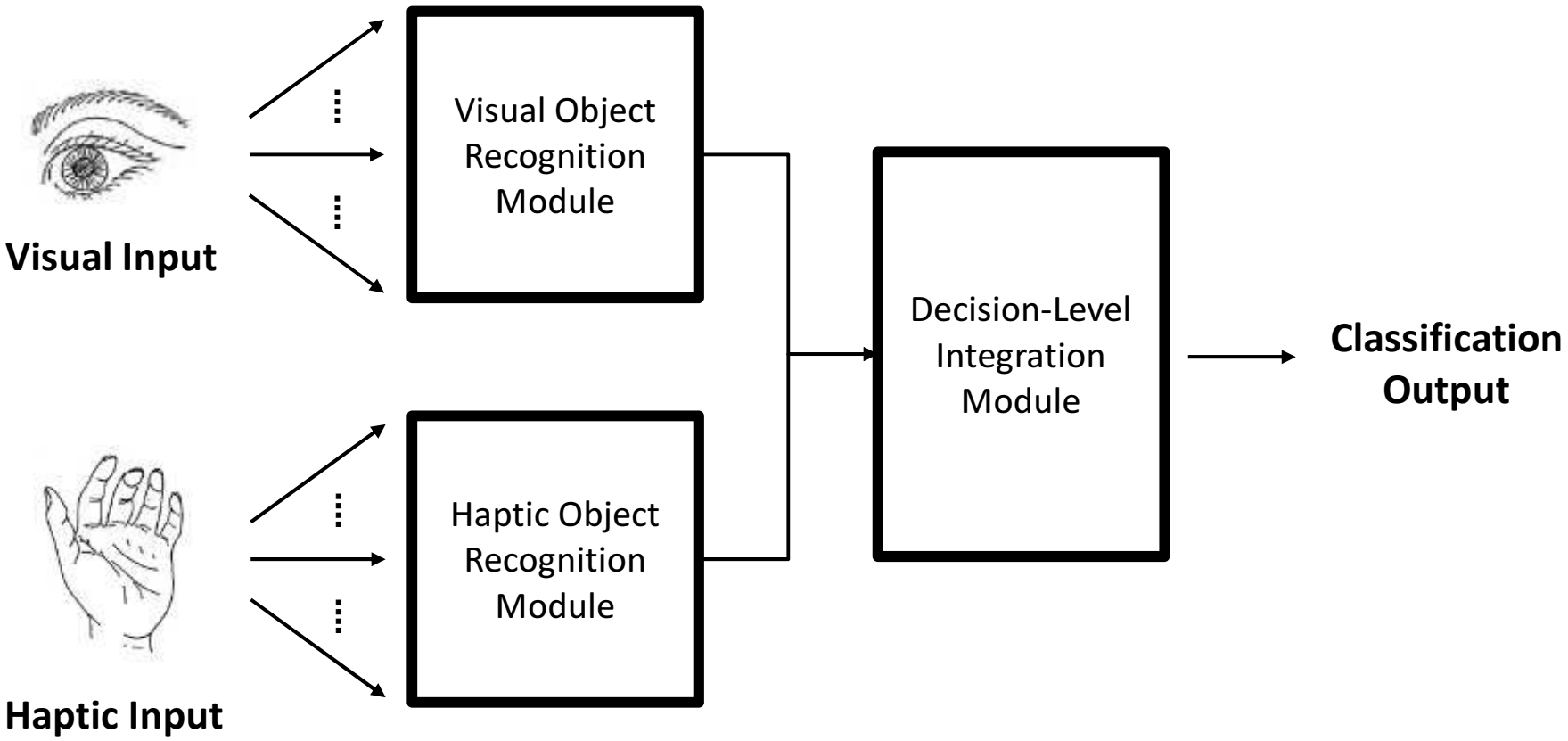
  ⇒Next slide

Cortical Sensory Areas in the Brain



http://www.d.umn.edu/~jfitzake/Lectures/DMED/SensoryPhysiology/GeneralPrinciples/CodingTheories.html

Decision-Level Integration



Issues

- **Dominance of vision over haptics**

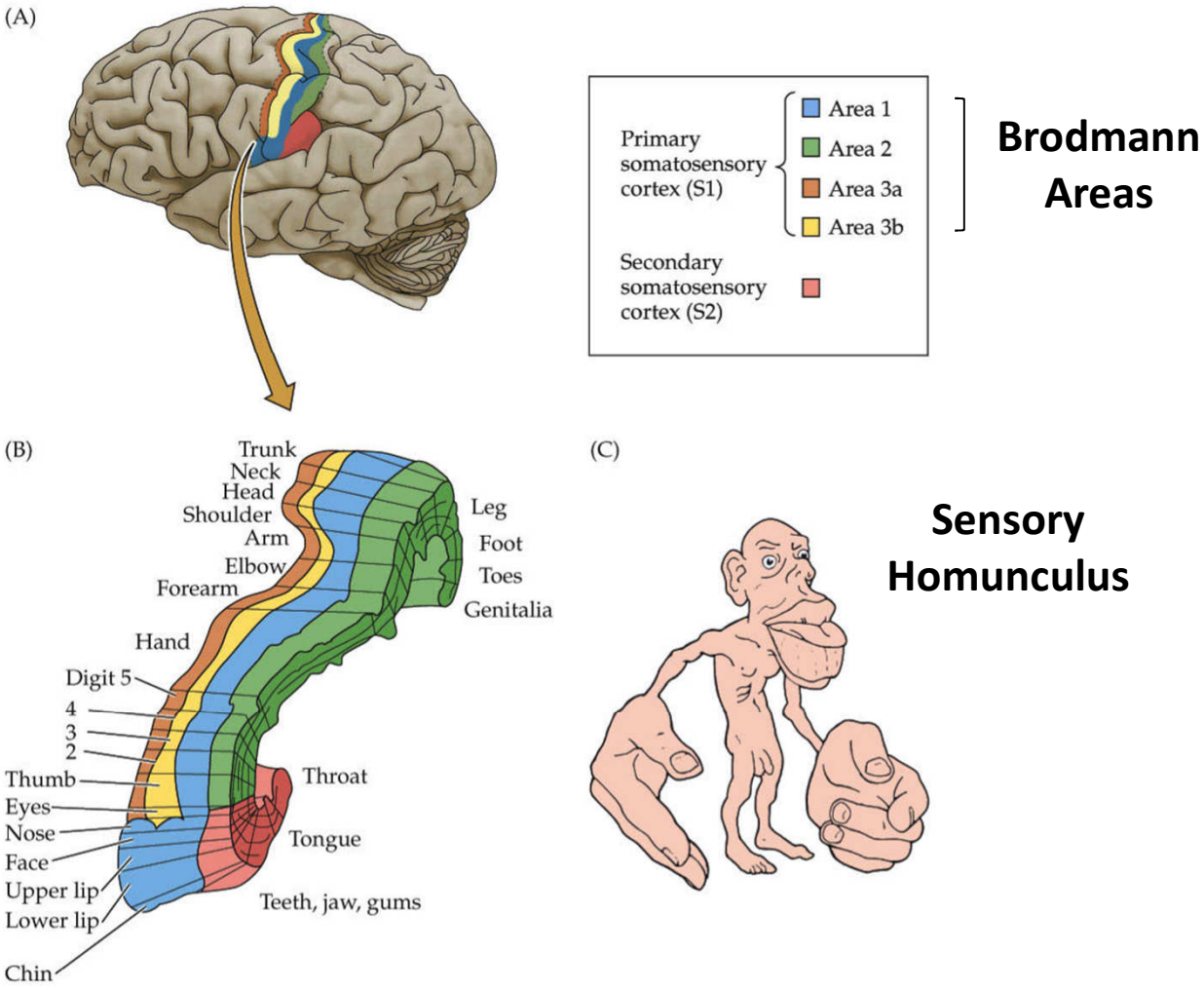
  ⇒Result of haptic part might not be needed

  ⇒Waste of computational effort

- **Recent neuroscientific counterevidence**

  ⇒Next slides

Somatosensory Cortex



Brodmann Areas

Hierarchical processing of somatosensory information

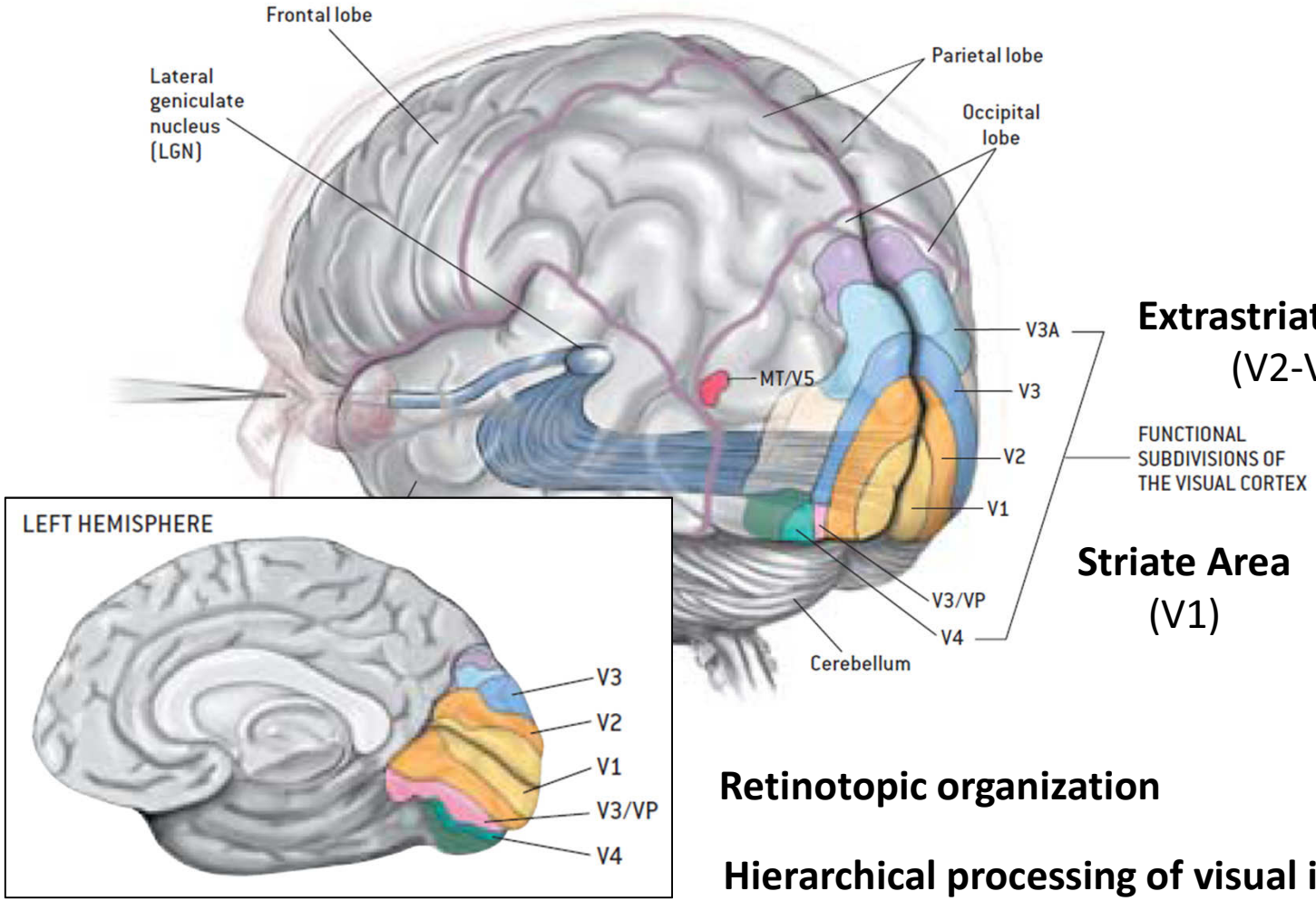
Somatotopic organization

Sensory Homunculus

***NEUROSCIENCE, Fourth Edition*, Figure 9.11**

https://classconnection.s3.amazonaws.com/698/flashcards/723698/png/untitled1319491580334.png

Visual Cortex



Extrastriate Areas
(V2-V5)

Striate Area
(V1)

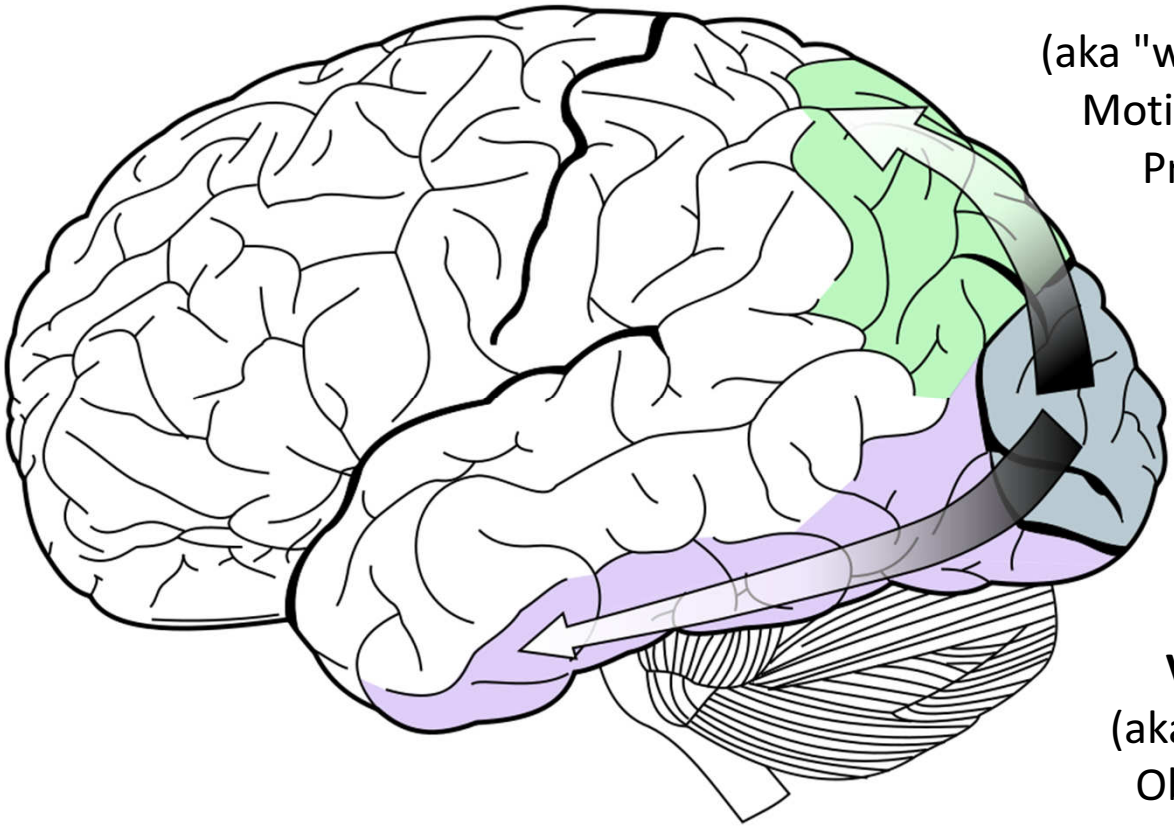
Retinotopic organization

Hierarchical processing of visual information

http://people.brandeis.edu/~teuber/Vision.pdf

Ventral and Dorsal Streams

[Goodale and Milner, 1992; Ungerleider and Mishkin, 1982]



Dorsal Stream:
(aka "where/ how pathway")
Motion/ Object Location
Processing Stream

Primary Visual (Striate) Cortex

Ventral Stream: ← !
(aka "what pathway")
Object Recognition
Processing Stream

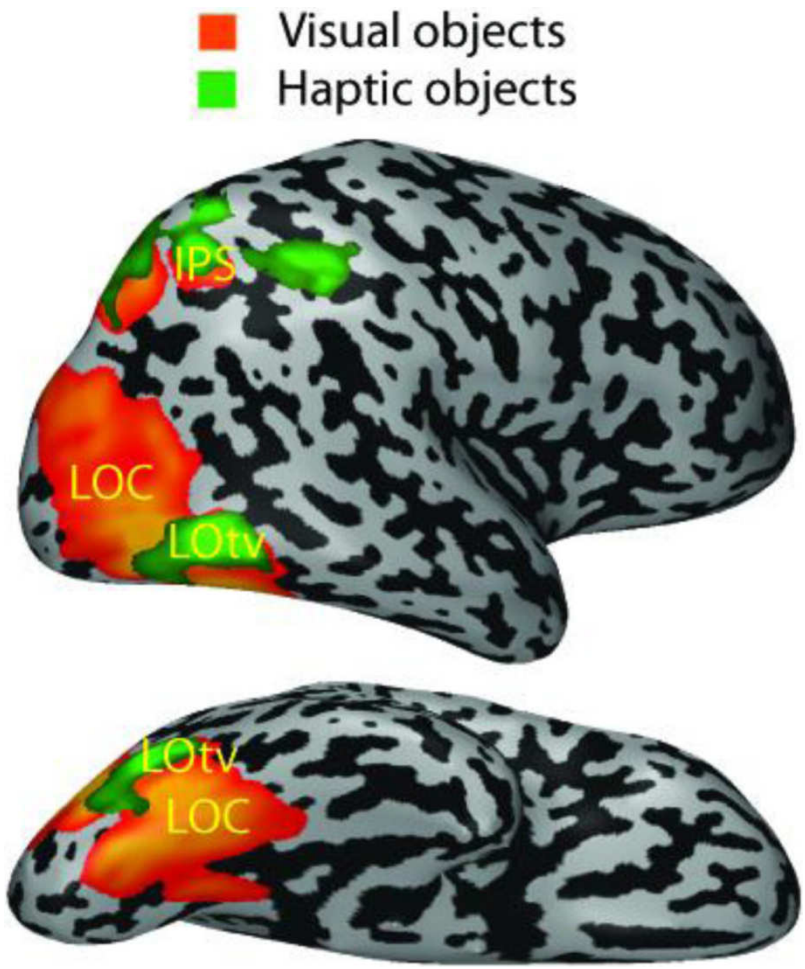
https://commons.wikimedia.org/wiki/File:Ventral-dorsal_streams.svg

Lateral Occipital Complex

[Lacey et al., 2009; Amedi et al., 2001]

Object-related regions in the visual and haptic modalities

Subregion of LOC responds selectively to objects in both vision and touch

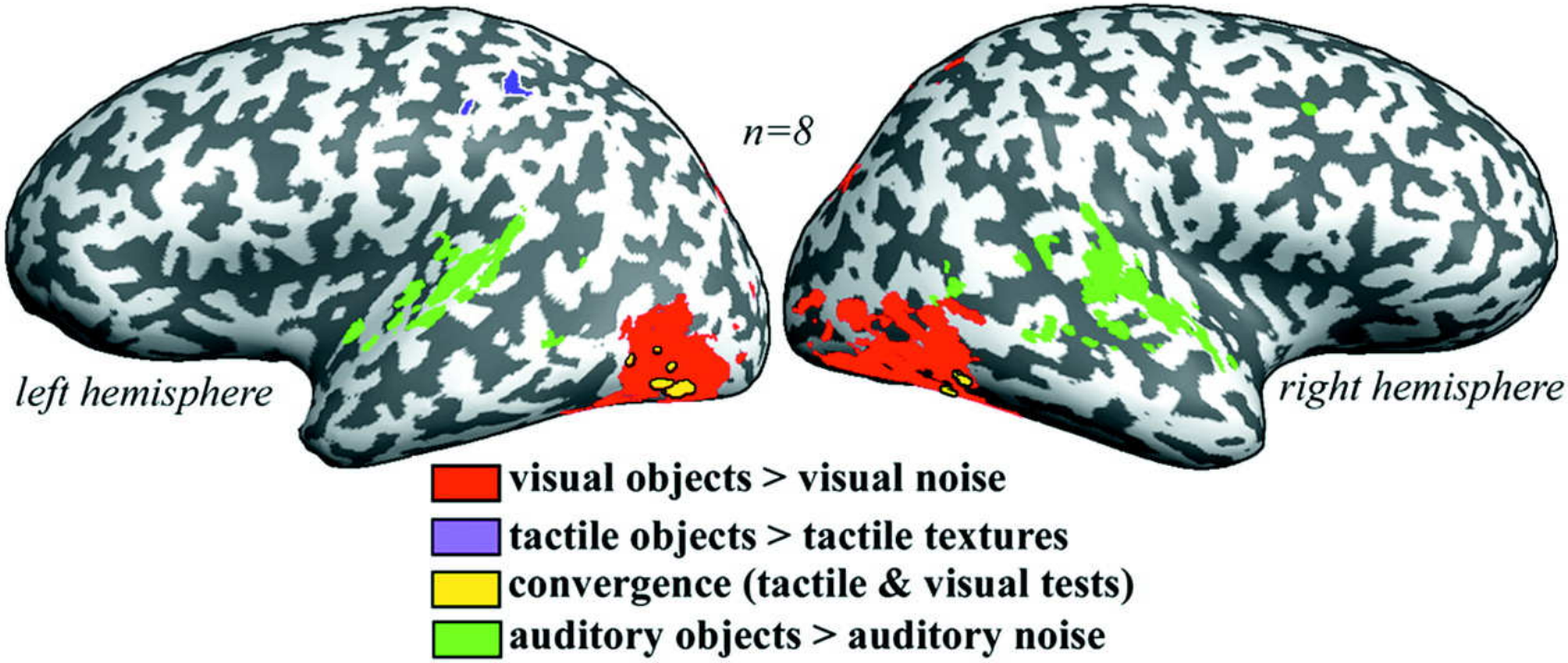


Lateral View

Ventral View

Lateral Occipital Complex

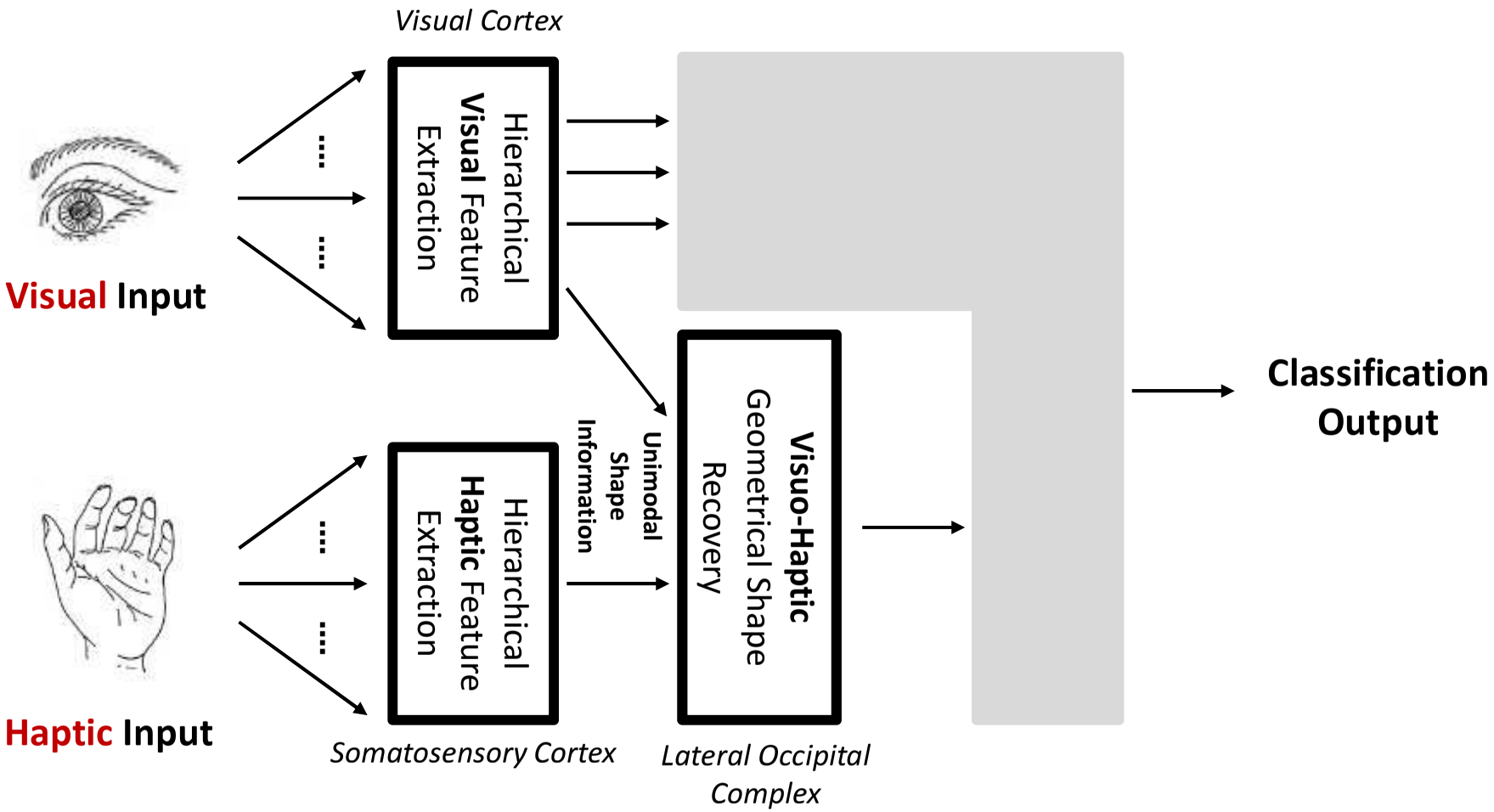
[Amedi et al., 2002]



Object-related regions in the visual, tactile and auditory modalities → No auditory object-related activation observed in LOC → LOC involved in the recovery of geometrical shape of objects

http://cercor.oxfordjournals.org/content/12/11/1202/F2.full

Interim Conclusion

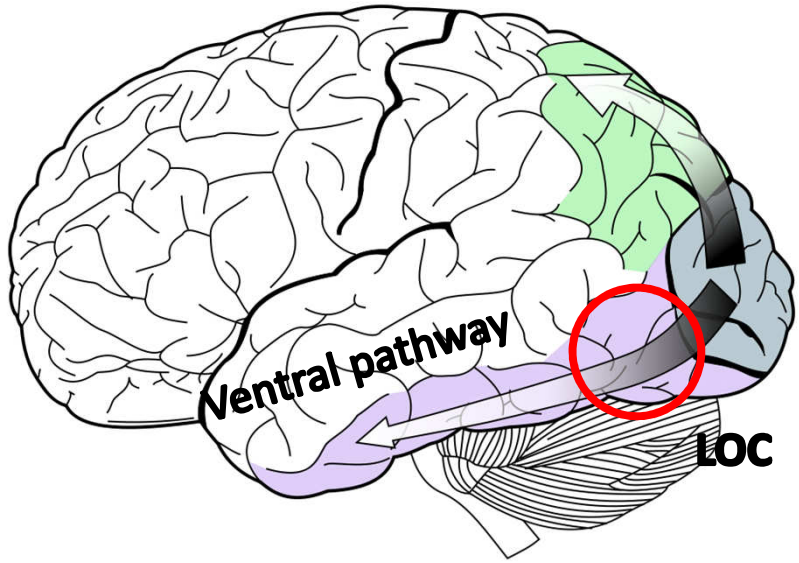


Open Questions

Question 1:

- LOC at a pretty early stage of the ventral pathway
- Apparently not responsible for object recognition per se

⇒ **Basically:** When and how does object recognition actually occur?



https://commons.wikimedia.org/wiki/File:Ventral-dorsal_streams.svg

Open Questions

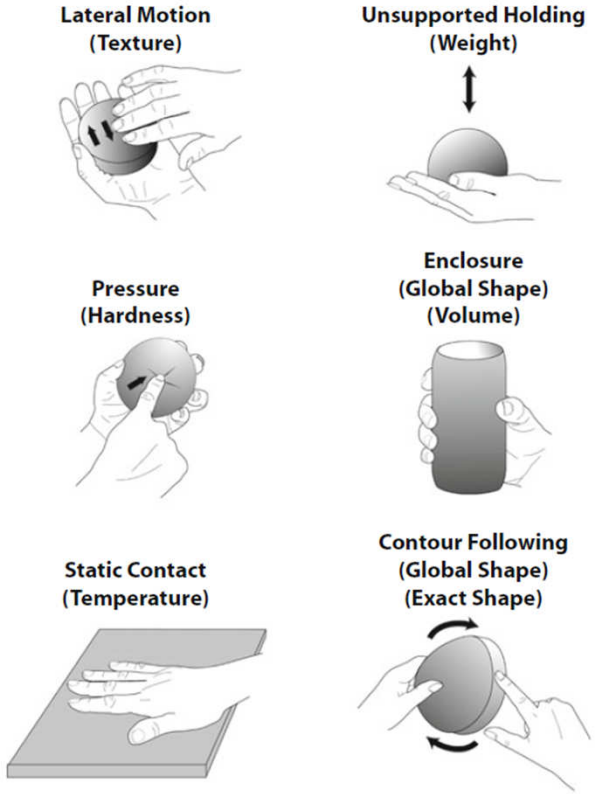
Question 2:

- Further **visuo-haptically** perceivable object properties: *Texture* and *volume/ size*

⇒ No integration?

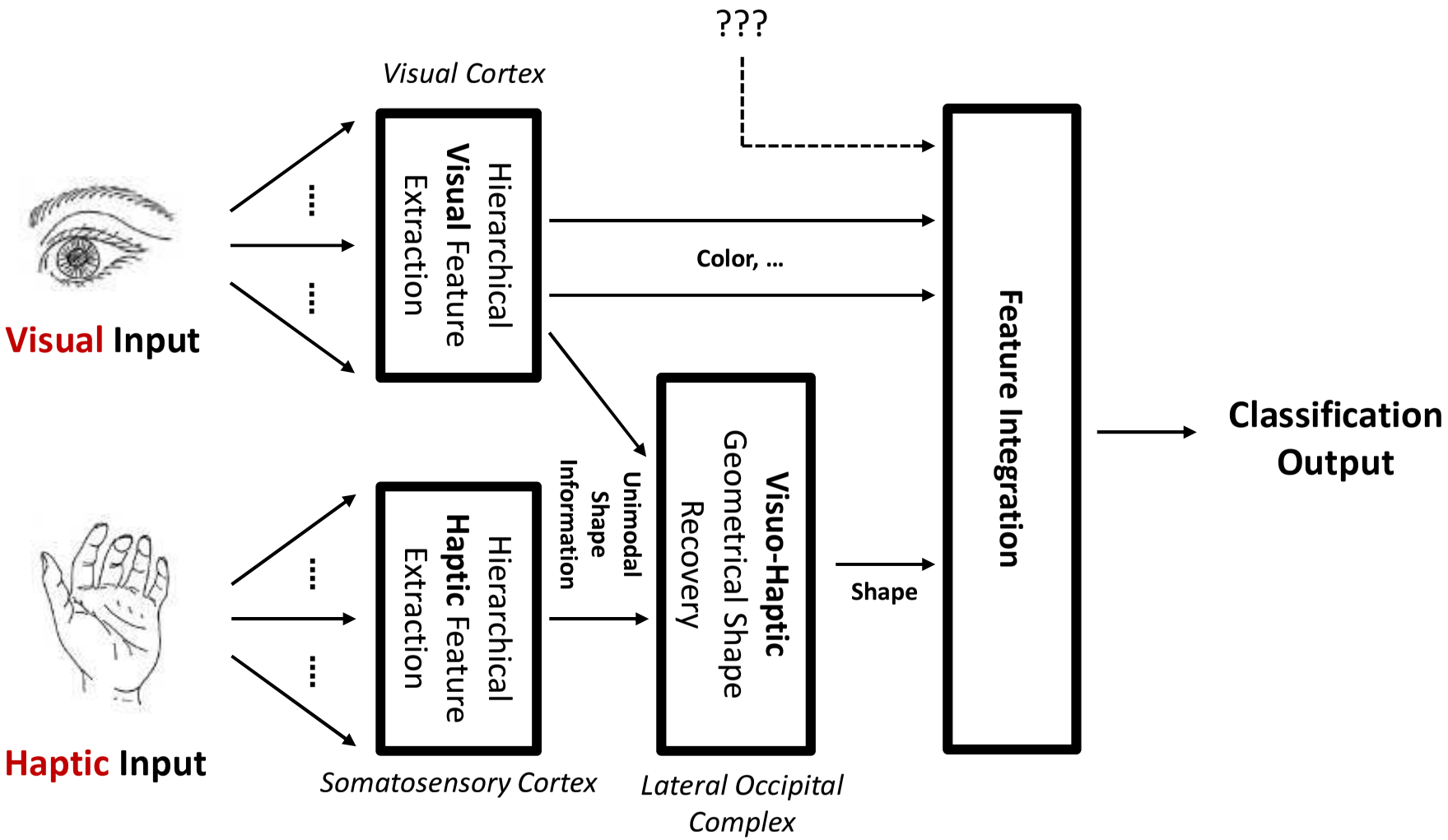
- **Only haptically** perceivable: *Hardness*, *temperature* and *weight*
- **Only visually** perceivable: *Color*, …

⇒ (Any) role in object recogn.?



[Lederman and Klatzky, 2009]

Feature-Level Integration



Summary

Question: How to integrate vision and haptics for more robust object recognition?

Possible Integration Strategies:

(1) Sensory-Level

(2) Decision-Level

(3) Feature-Level

Conclusion: (3) → Good starting point to investigate the importance of shape in object recognition

References

- Lederman, Susan J., and Roberta L. Klatzky. "Haptic perception: A tutorial."*Attention, Perception, & Psychophysics* 71.7 (2009): 1439-1459.
- Lederman, Susan J., and Roberta L. Klatzky. "Hand movements: A window into haptic object recognition." *Cognitive psychology* 19.3 (1987): 342-368.
- Amedi, Amir, et al. "Functional imaging of human crossmodal identification and object recognition." *Experimental Brain Research* 166.3-4 (2005): 559-571.
- Goodale, Melvyn A., and A. David Milner. "Separate visual pathways for perception and action." *Trends in neurosciences* 15.1 (1992): 20-25.
- Mishkin, Mortimer, Leslie G. Ungerleider, and Kathleen A. Macko. "Object vision and spatial vision: two cortical pathways." *Trends in neurosciences* 6 (1983): 414-417.
- Lacey, Simon, et al. "A putative model of multisensory object representation." *Brain topography* 21.3-4 (2009): 269-274.
- Amedi, Amir, et al. "Visuo-haptic object-related activation in the ventral visual pathway." *Nature neuroscience* 4.3 (2001): 324-330.
- Amedi, Amir, et al. "Convergence of visual and tactile shape processing in the human lateral occipital complex." *Cerebral Cortex* 12.11 (2002): 1202-1212.
- Ungerleider, Leslie G., and Luiz Pessoa. "What and where pathways." *Scholarpedia* 3.11 (2008): 5342.