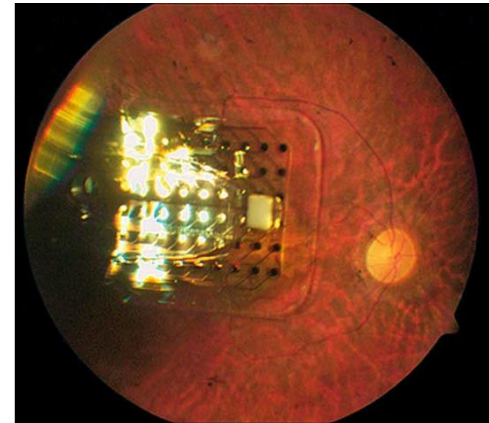
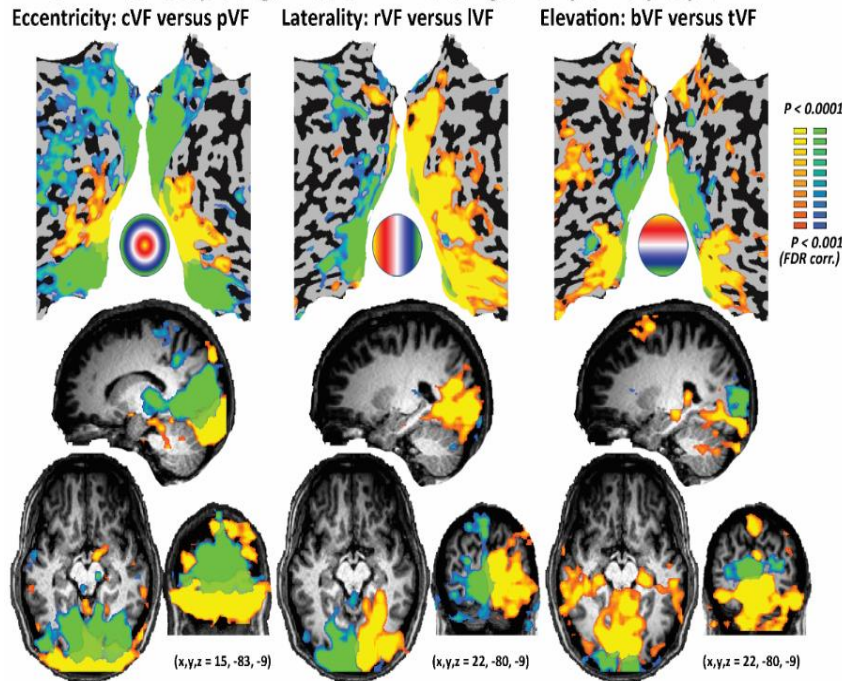


Science, Technology & Rehab in sensory impairment: where brain science and machine vision meet?

A fcMRI retinotopic organization in MO congenitally blind people



Photograph by Second Sight Medical Products



@AmediLab
[Http://brain.huji.ac.il](http://brain.huji.ac.il)

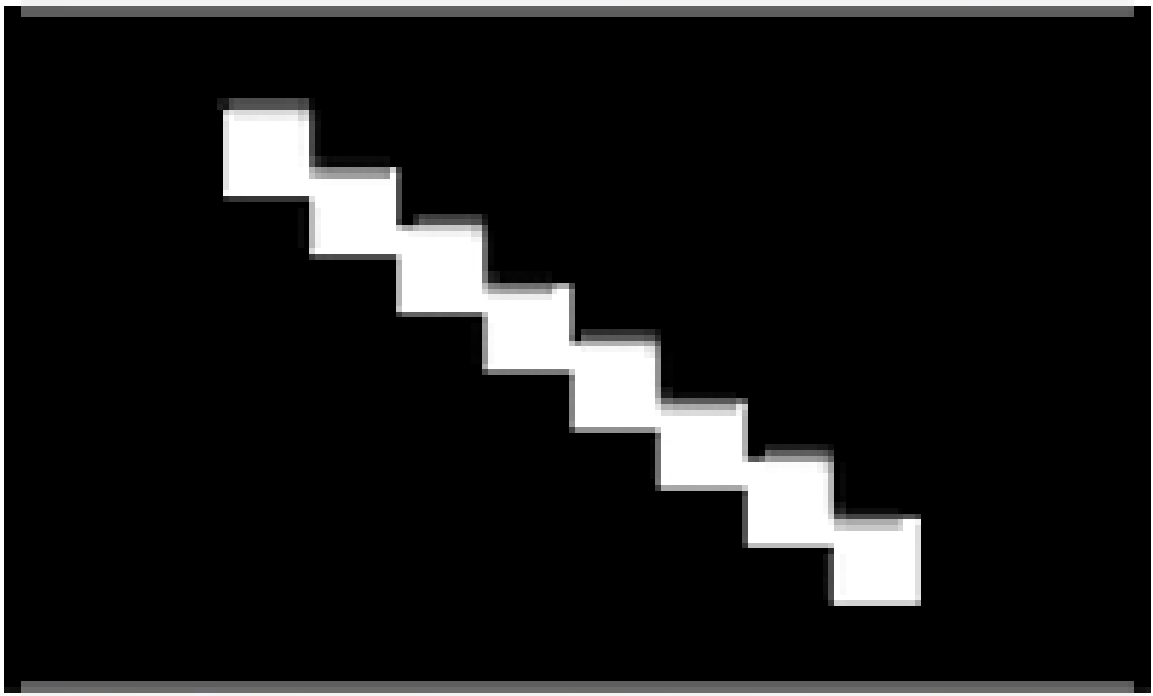
האוניברסיטה העברית בירושלים
 The Hebrew University of Jerusalem



Institute for
 Medical
 Research
 Israel-Canada
 INNOVATIONS TOUCHING LIVES



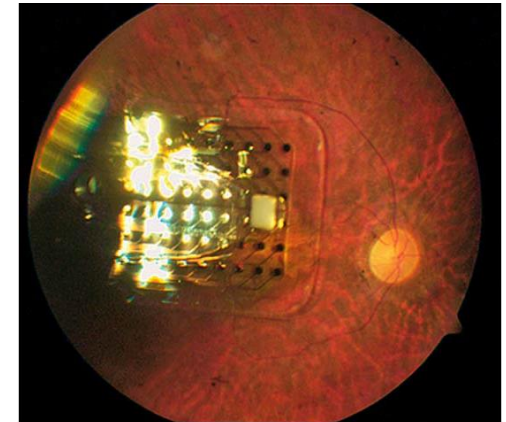
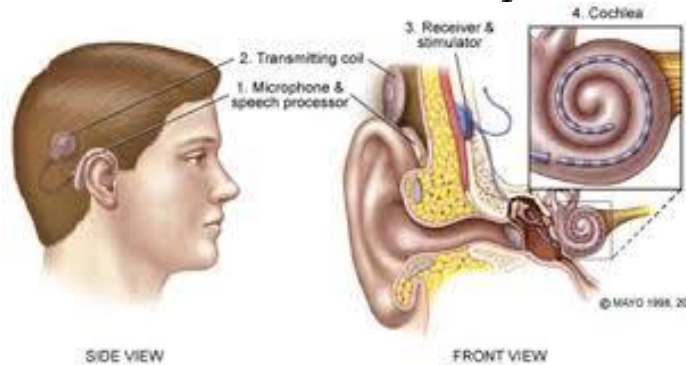
ELSC
 The Edmond & Lily Safra
 Center for Brain Sciences



Cyborgs – the revolution already started

Implants and the way they interact with our brain

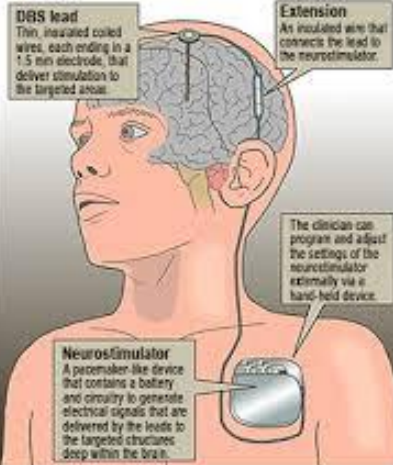
(Bionic eye; ears; arms; DBS; NewSenses vs. ReNewSenses)



Photograph by Second Sight Medical Products

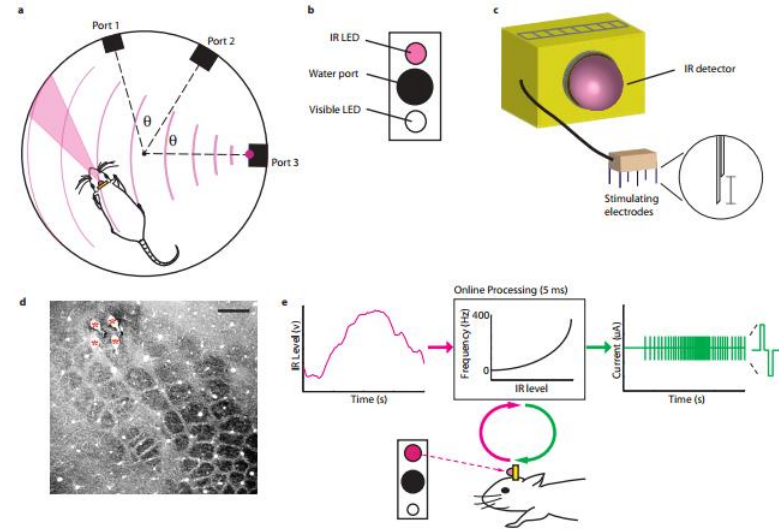
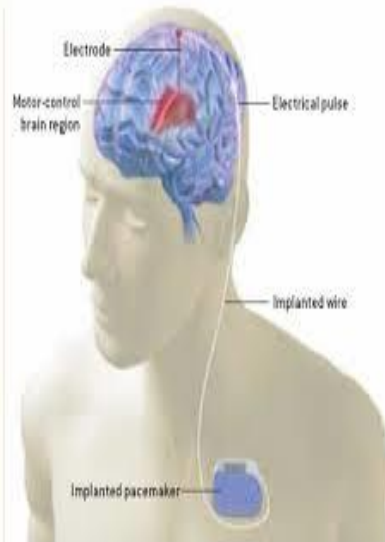
Deep brain stimulation

The Deep Brain Stimulation system is used to help control tremors and chronic movement disorders. Tiny electrodes are surgically implanted in the brain and are connected via a subcutaneous wire to a neurostimulator (or two, for some diseases) implanted under the skin near the clavicle.



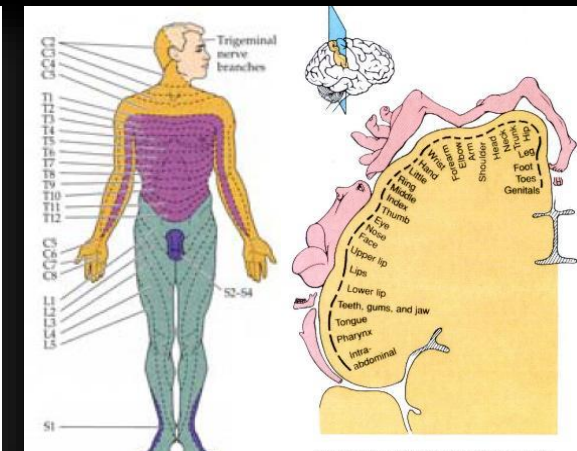
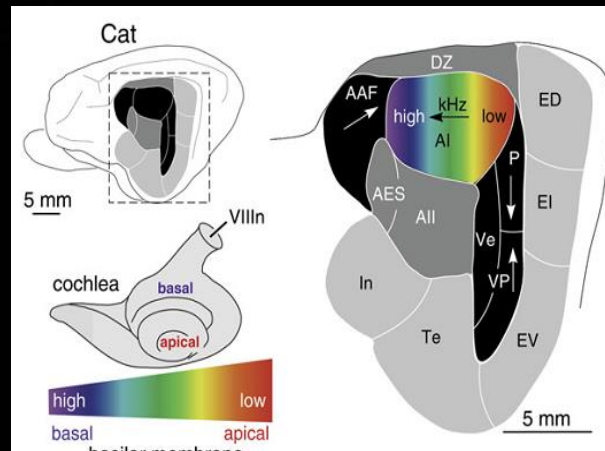
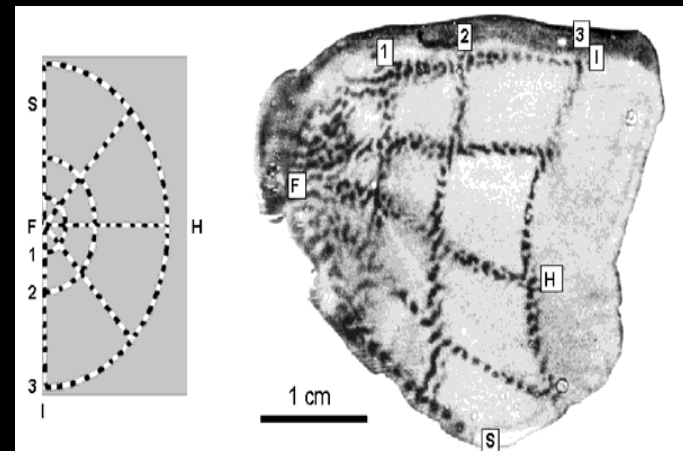
Source: Medtronic Inc.

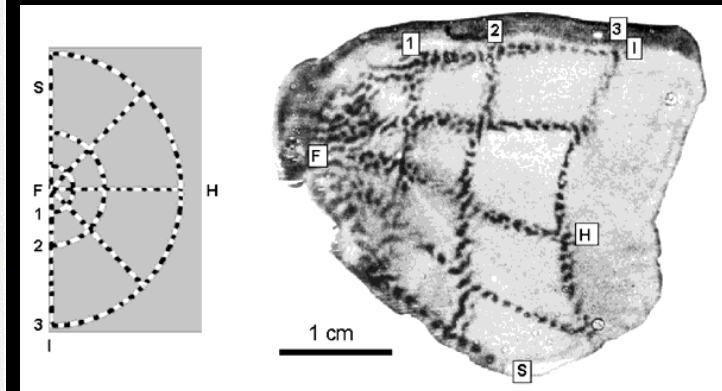
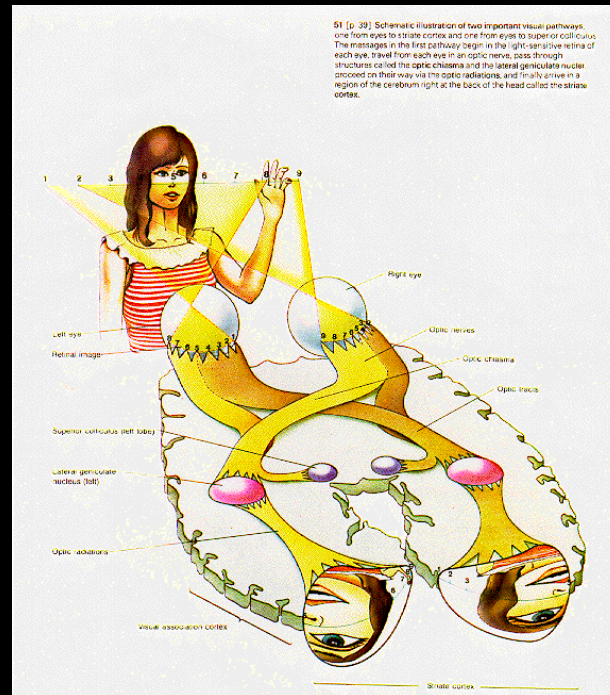
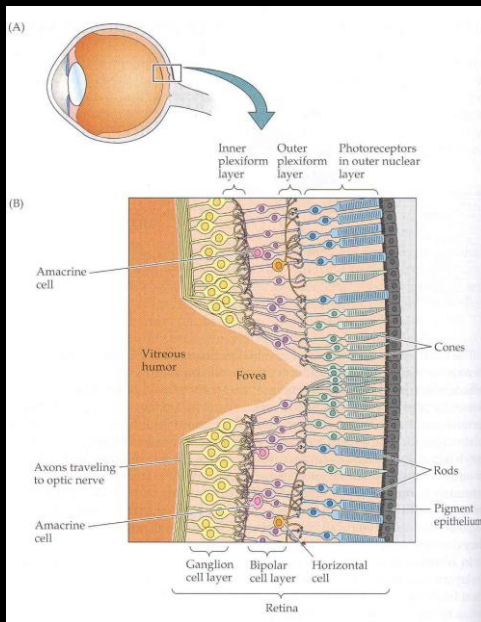
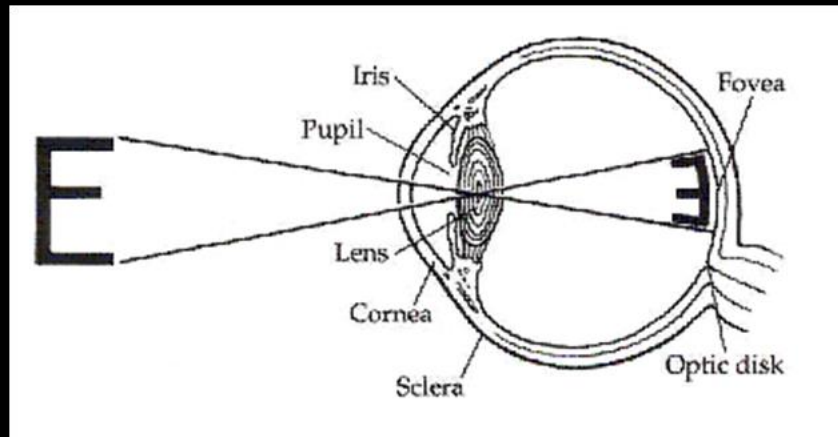
Steve Greenberg / Star staff



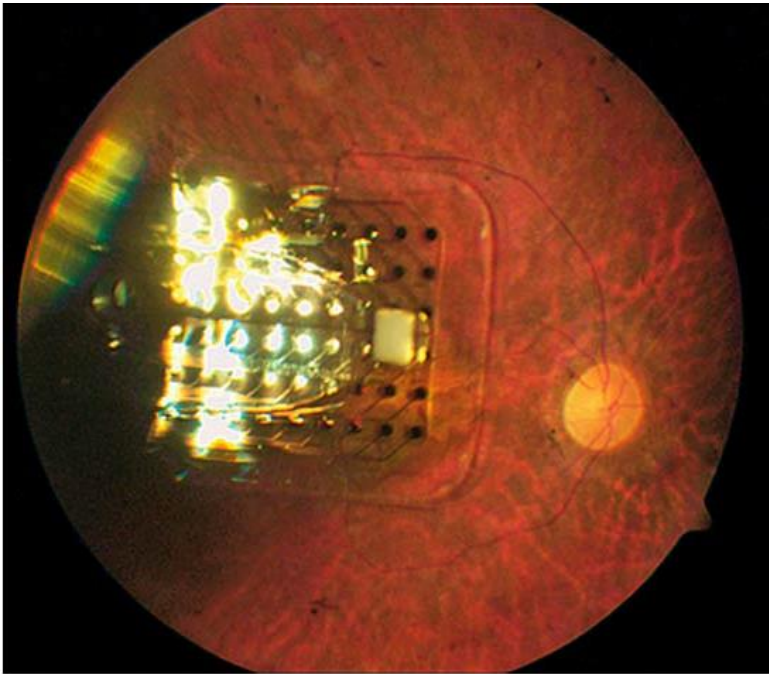
Introduction – the topographical brain

- Topographical senses – vision, audition and touch - sensory epithelium to cortex plus motor system.
- Higher order topography (eye gaze, numbers and quantity, language? Memory? (distance of events from us) other?





Most exciting: visual prostheses (BUT very expensive, per ethology, very limited & require extensive rehab – even after months and hundreds of hours performance relatively weak in most patients and vary a lot - WHY?)



Photograph by Second Sight Medical Products

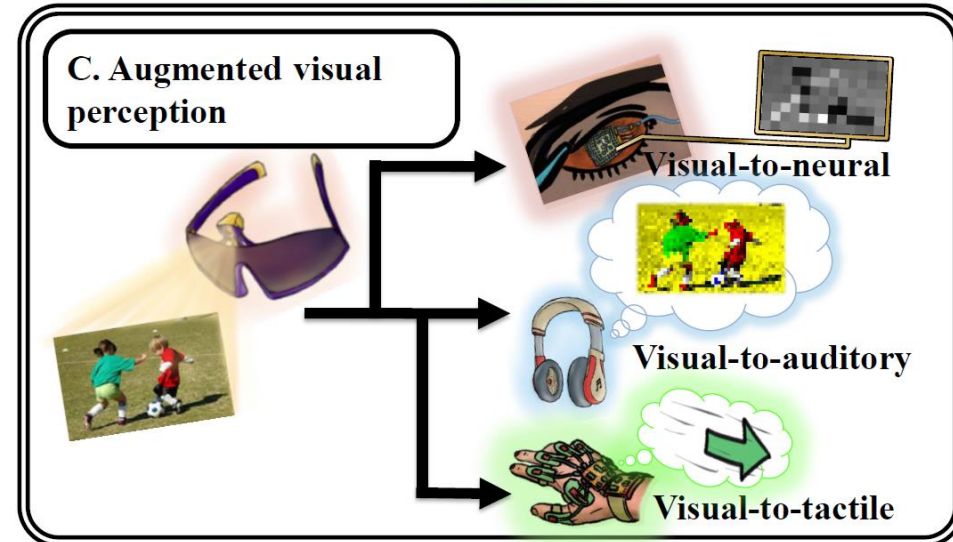
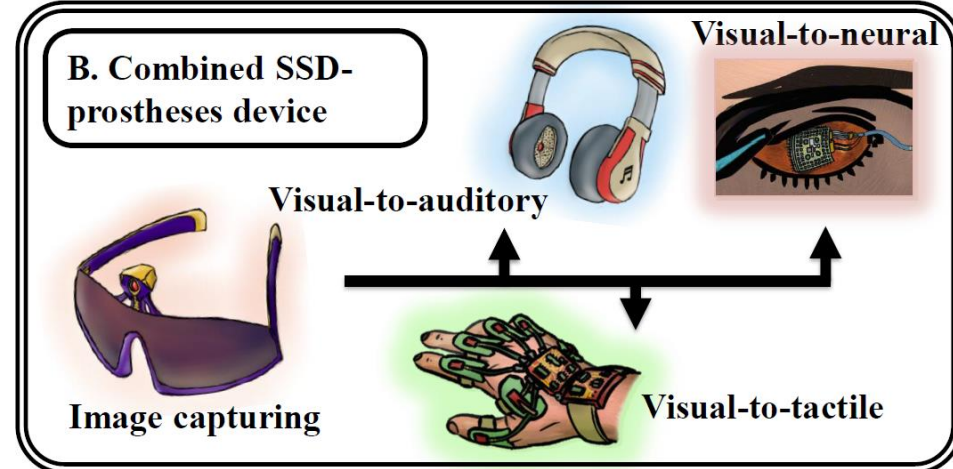


To explain partially why – let's make a little detour...

E.g. Argus II, second sight.
RP patients
Got FDA approval last year.

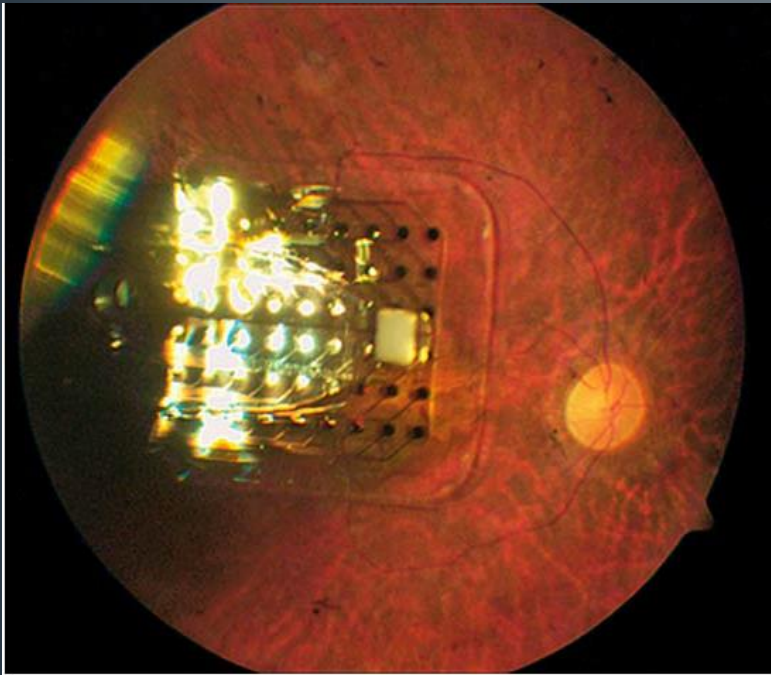
The multisensory bionic eye ERC project BrainVisionRehab (Amedi lab)

- (1) Training faster and better using SSD and Machine Vision
- (2) Increased resolution & color vision using SSDs and CV
- (3) Wider field of view
- (4) Qualia coming from prostheses but might be linked to the SSD and will increase qualia even non invasively



How can computer vision help us improve the situation in all these cases?

Most exciting: visual prostheses (BUT very expensive, per ethology, very limited & require extensive rehab – even after months and hundreds of hours performance relatively weak in most patients and vary a lot - WHY?)



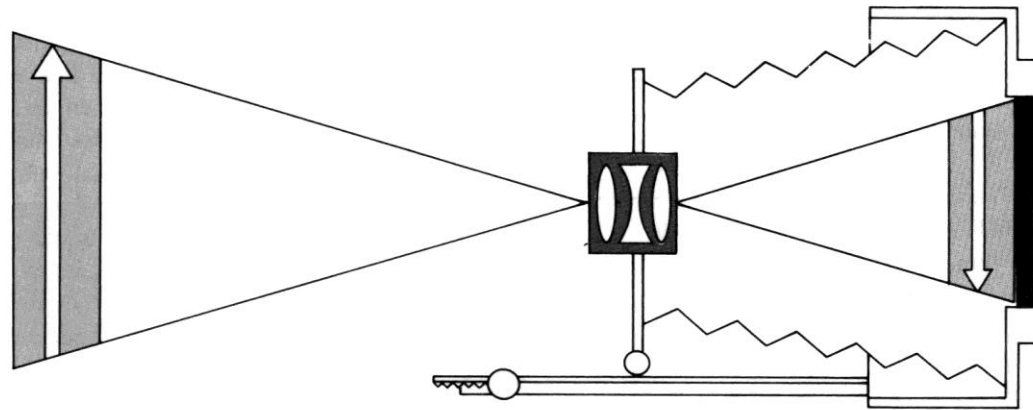
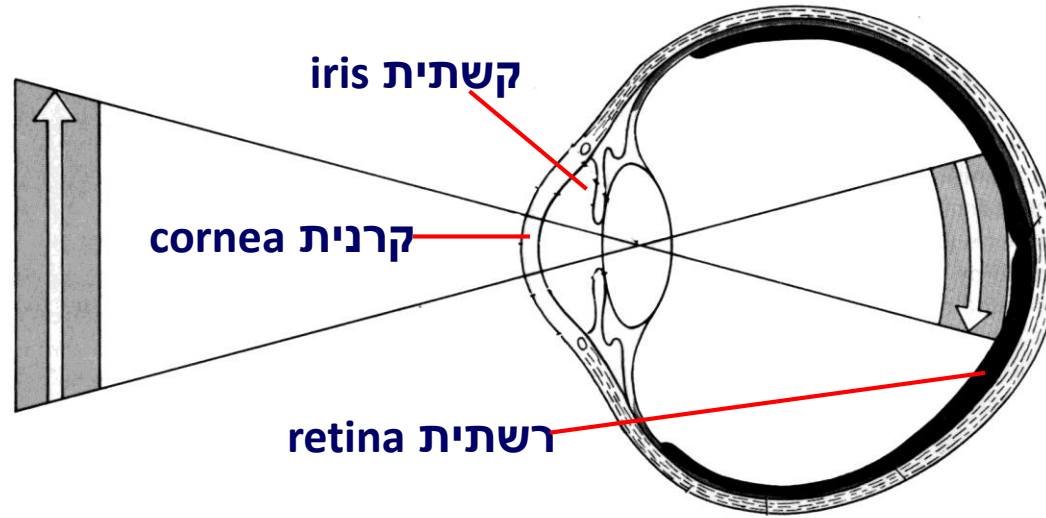
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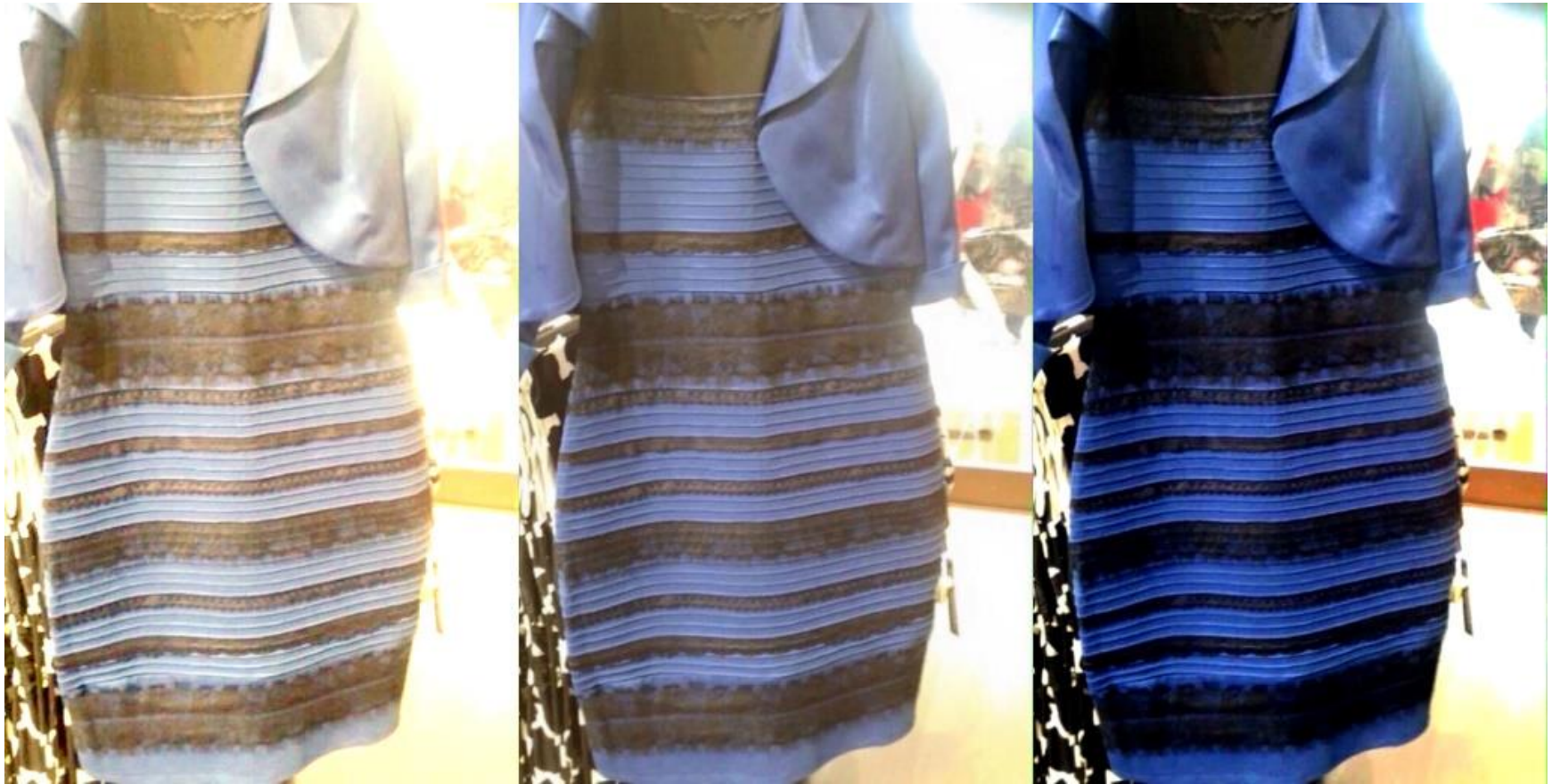
Vision = Camera?



We see with our brains, not less than
we see with our eyes.



What color is this dress?



Is it the same gray all over the line?



Color illusion

IS THE DRESS IN SHADOW?

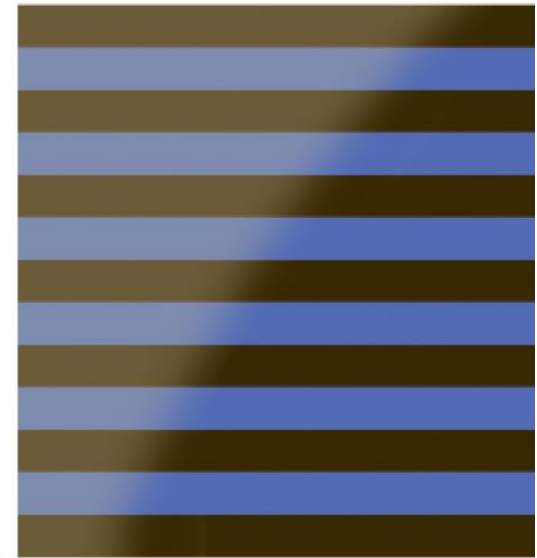
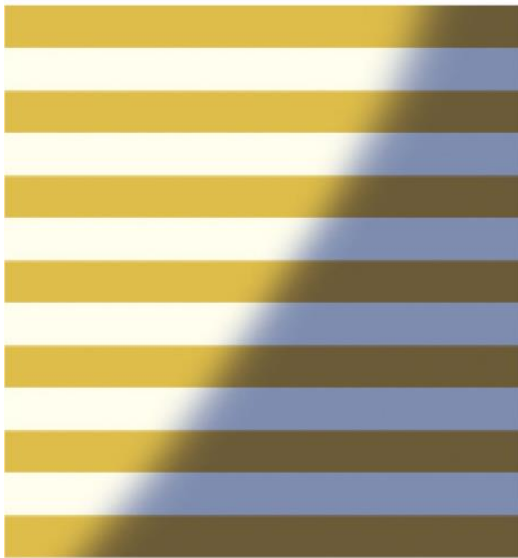
If you think the dress is in shadow, your brain may remove the blue cast and perceive the dress as being white and gold.

THE DRESS IN THE PHOTO

If the photograph showed more of the room, or if skin tones were visible, there might have been more clues about the ambient light.

IS THE DRESS IN BRIGHT LIGHT?

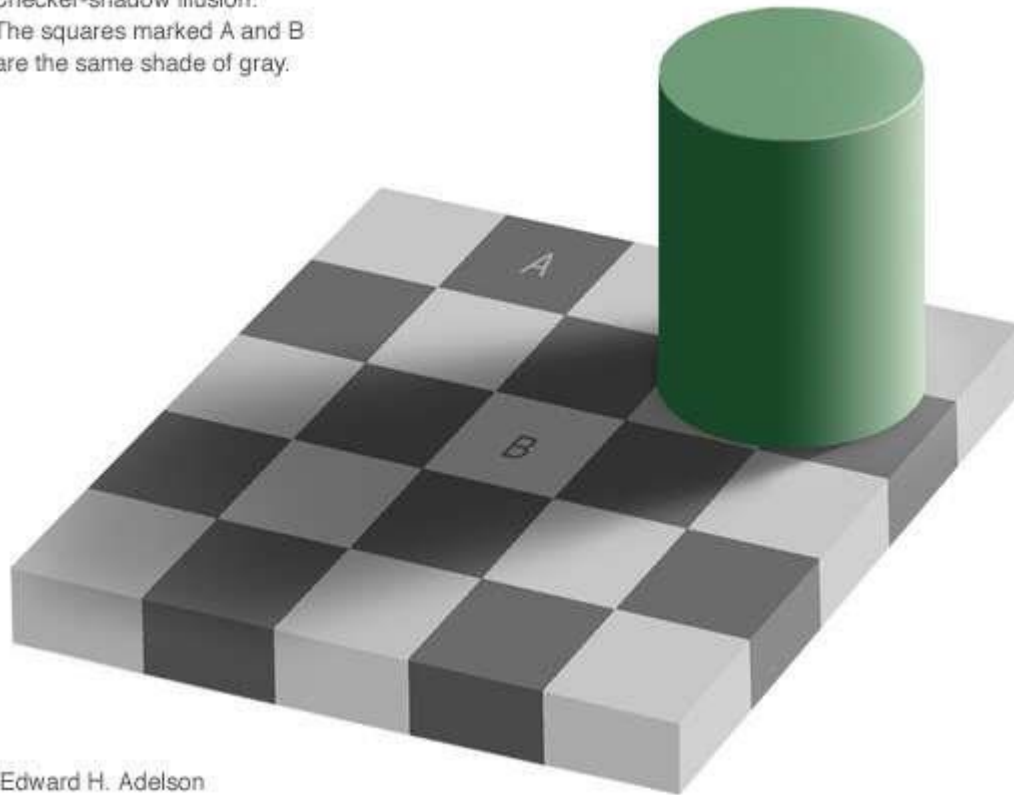
If you think the dress is being washed out by bright light, your brain may perceive the dress as a darker blue and black.



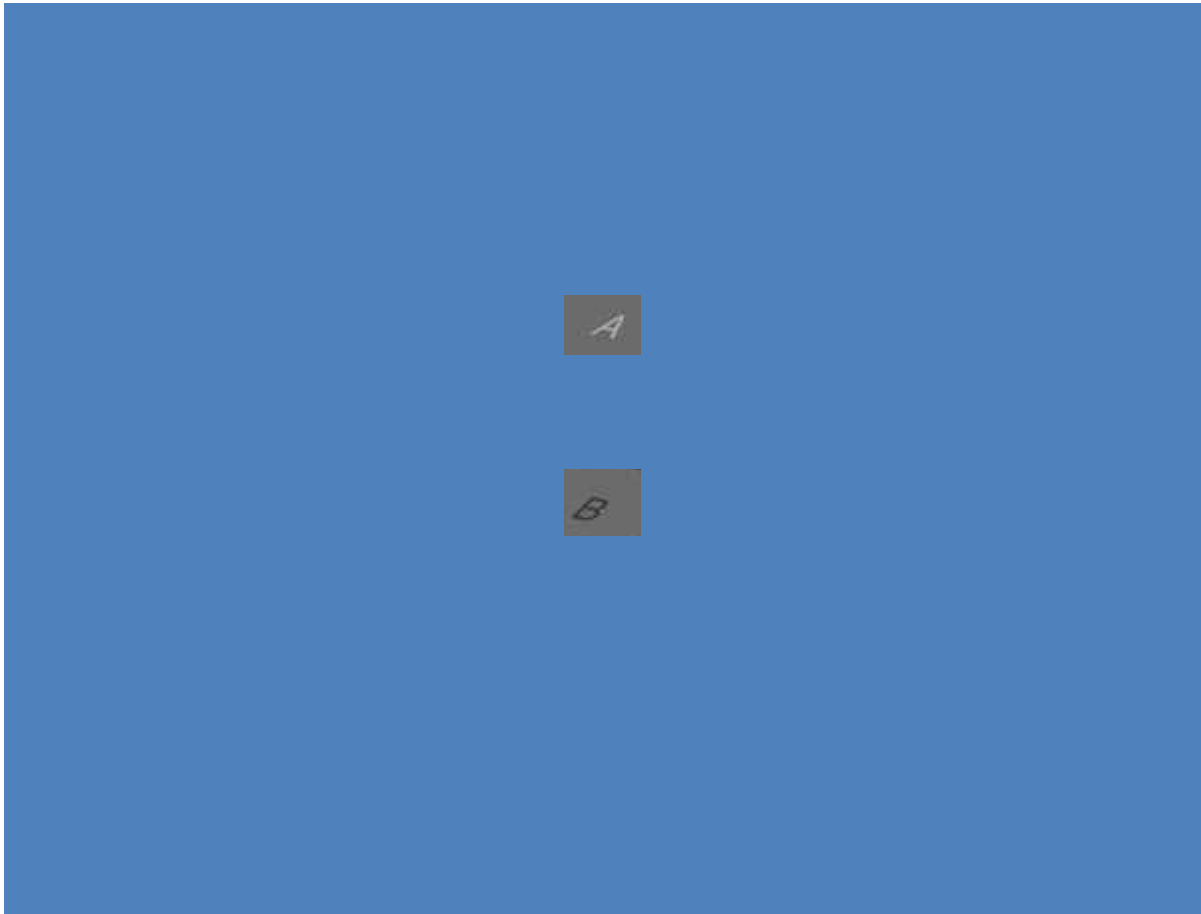
What color is this dress?



Checker-shadow illusion:
The squares marked A and B
are the same shade of gray.



Edward H. Adelson

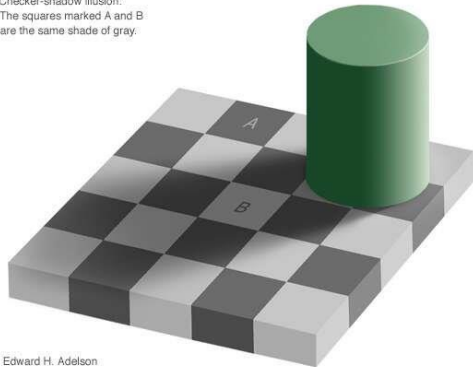


We see (hear and touch) with our brains, not less than we see with our eyes (ears and body)!

- Even objects
- Even something basic like color
- Even something basic like grayscale level

FedEx®

Checker-shadow illusion:
The squares marked A and B
are the same shade of gray.

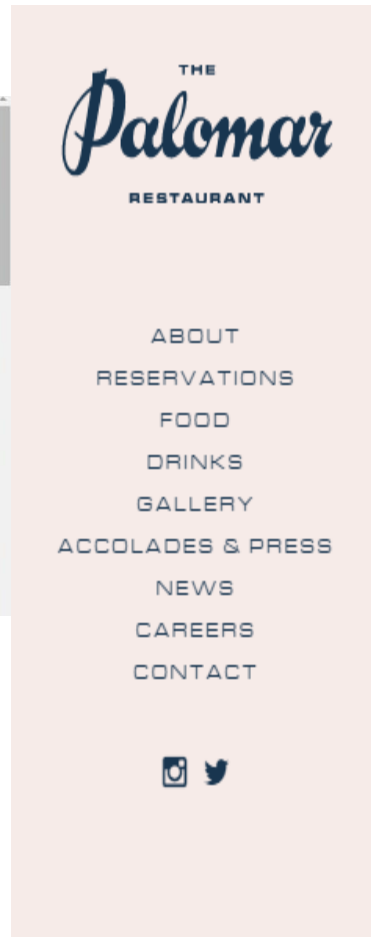


Edward H. Adelson



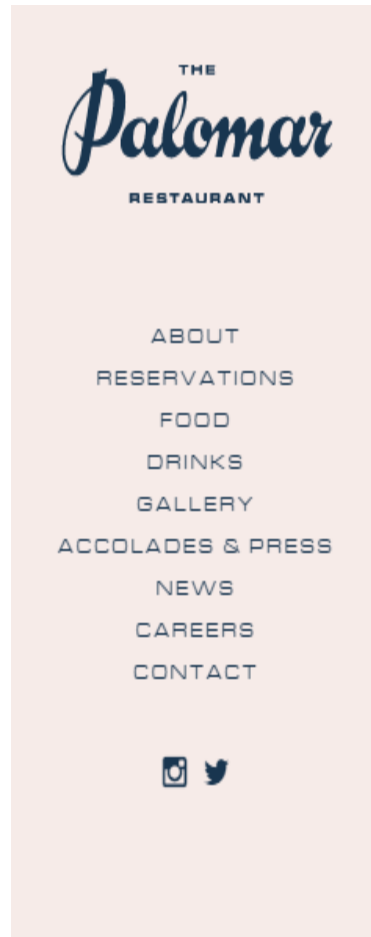
The Ultimate example...

Plus (not so) hidden advertisement

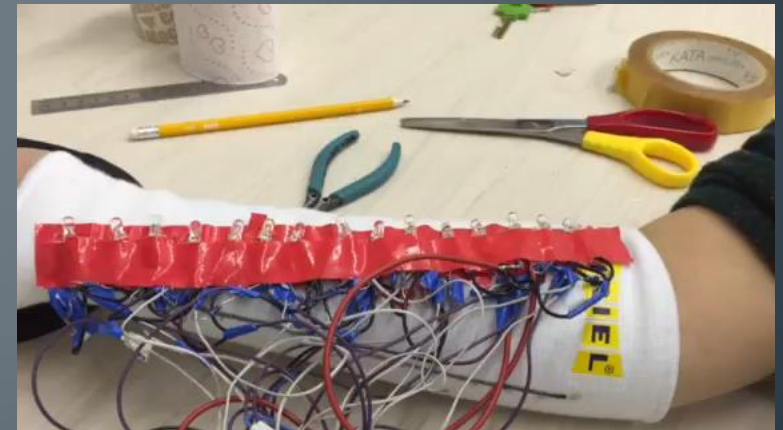


The Ultimate example...

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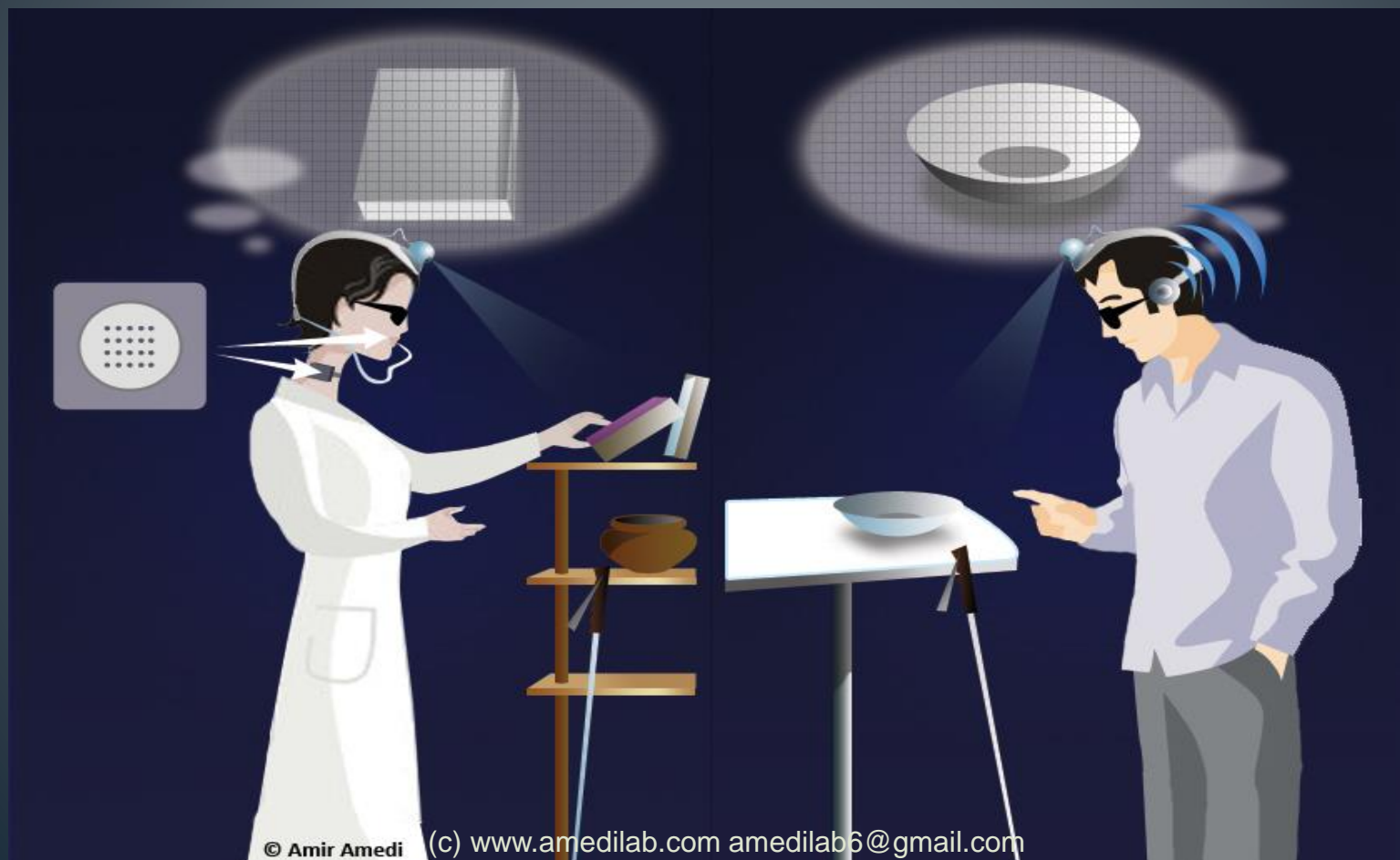


Paul Bach-y-Rita: so why not using it? Pioneering visual-to-tactile Sensory substitution devices

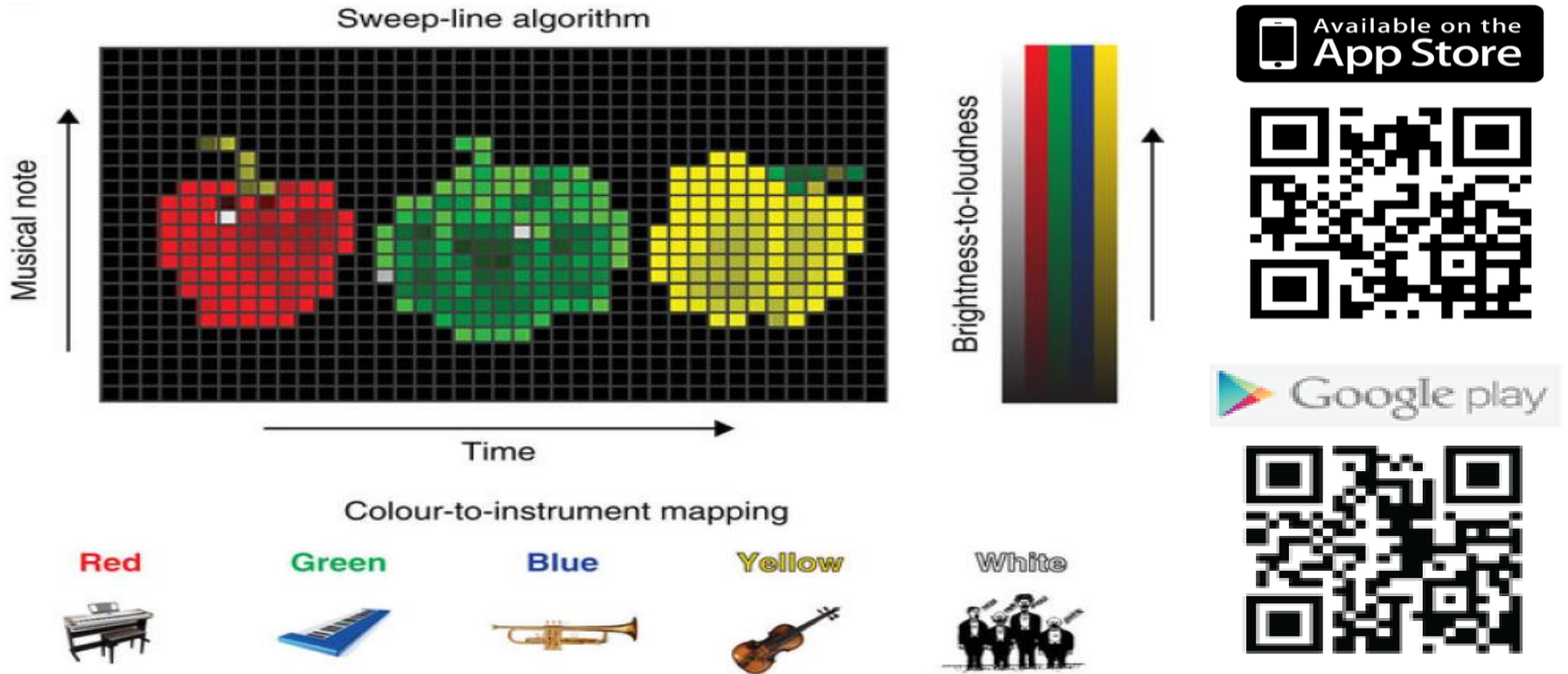


In collaboration with
Leo Joscovitz

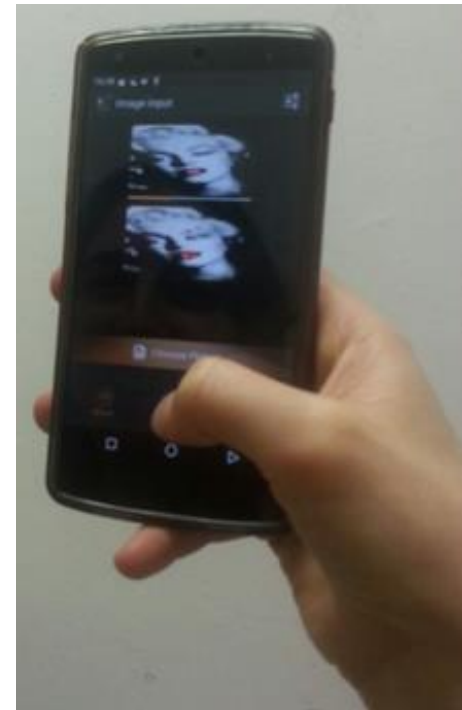
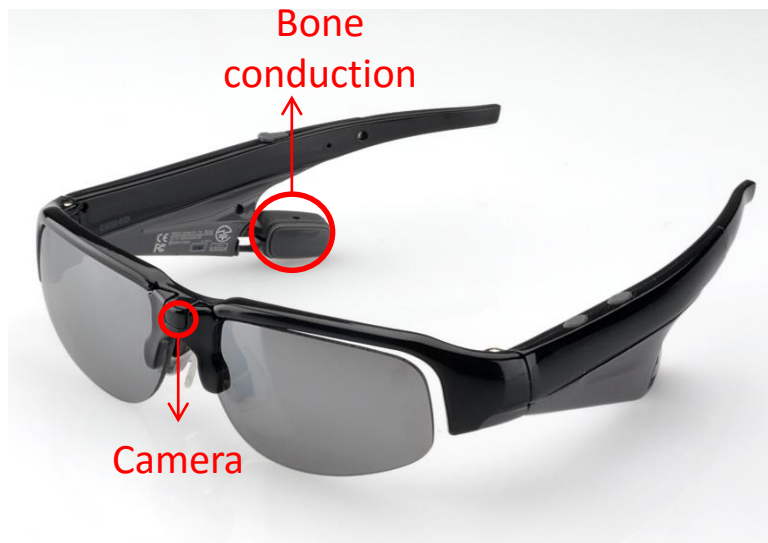
Vision is an active process - let's make a bypass to the brain via the other senses: Sensory substitution (Bach-y-Rita)



The EyeMusic



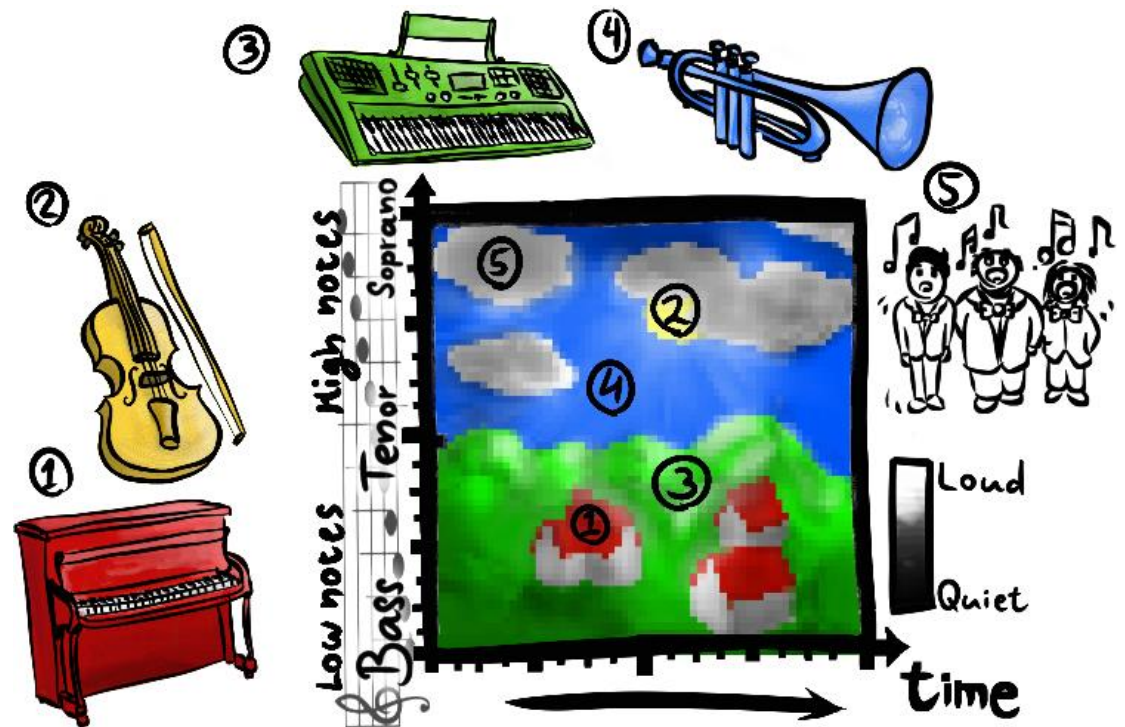
EyeMusic setups



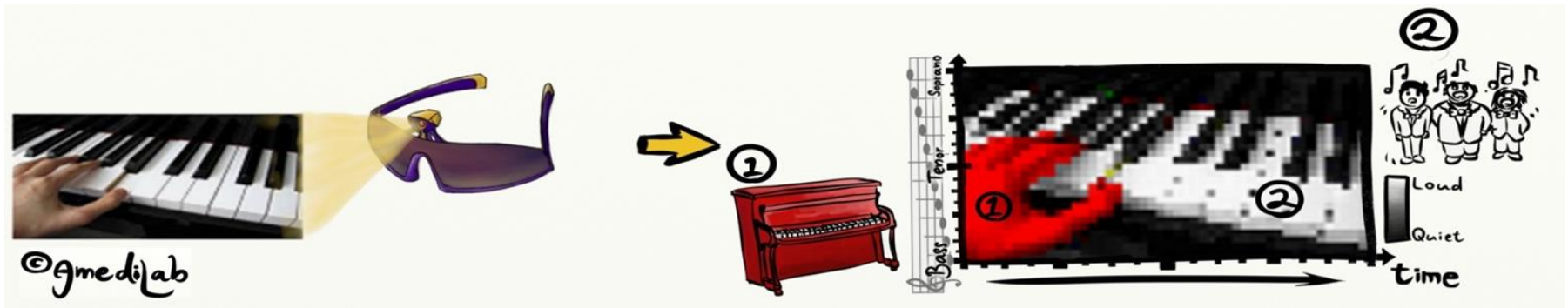
How does it work?

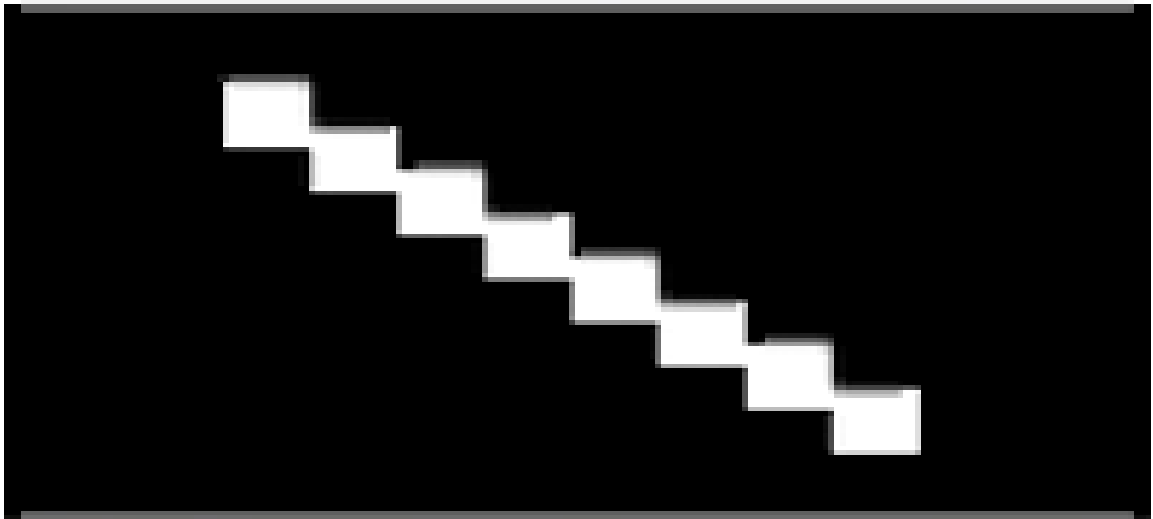
Resolution:
30X50 pixels

Refresh rate:
2.5 seconds
(but adjustable)



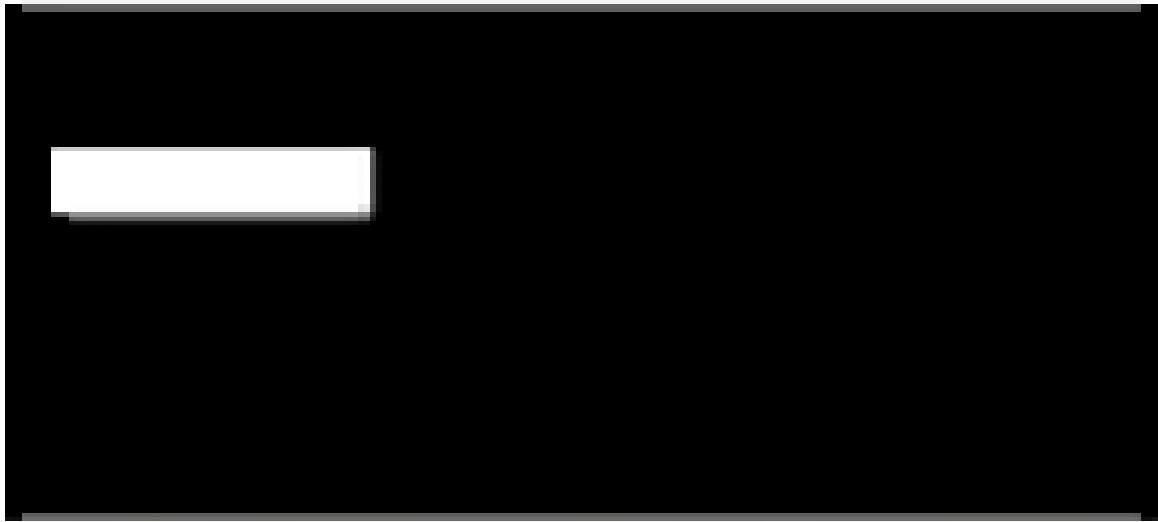
www.BrainVisionRehab.com





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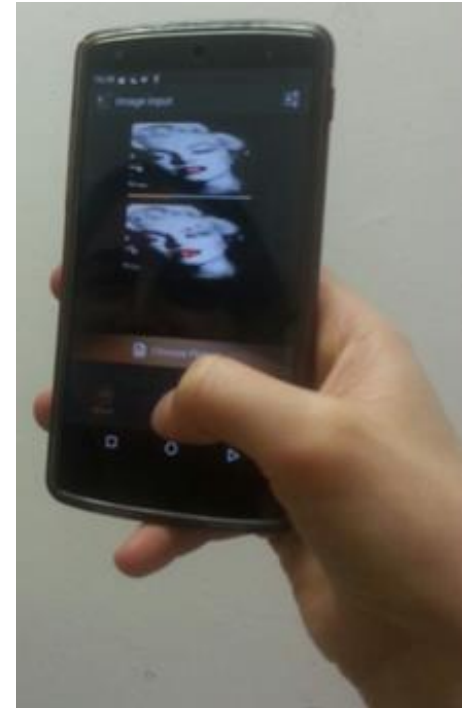
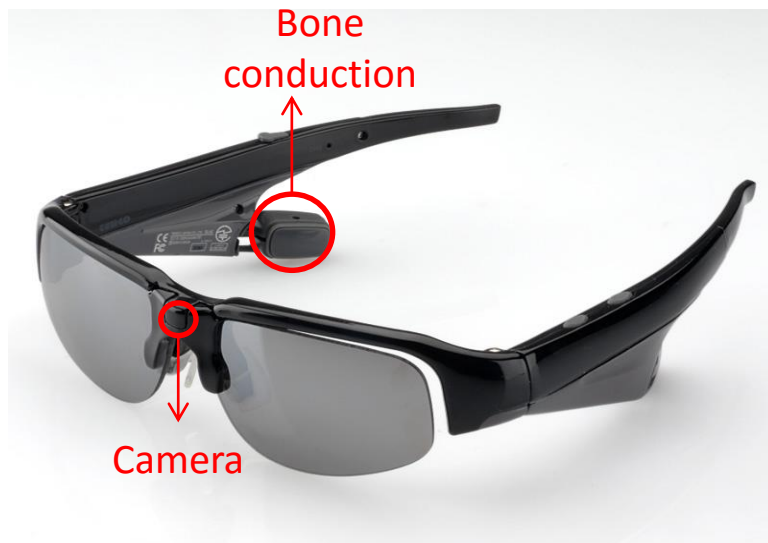
[Redacted text]

.....





EyeMusic setups



SSD can be relevant to learning images from real life situations):

Reading and numbers: (Neuron 2012, Current Biology 2014)

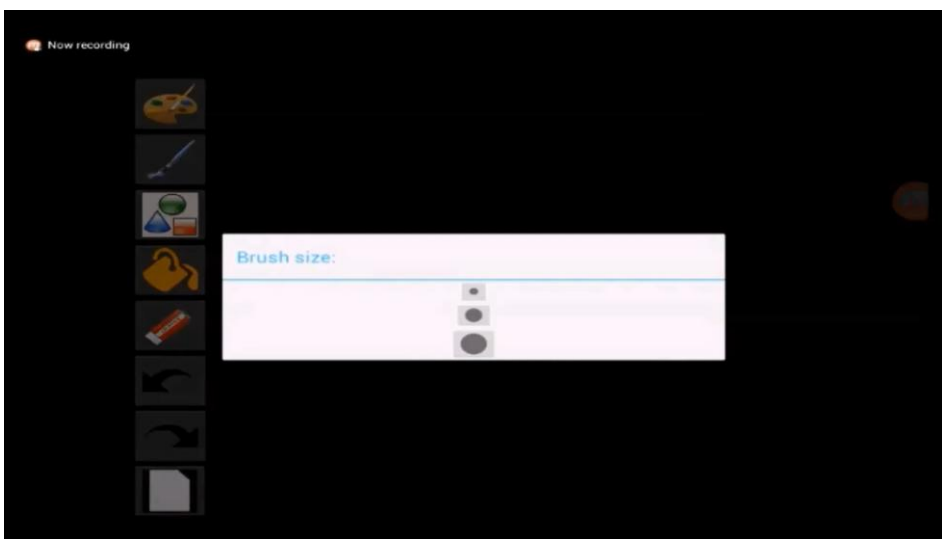
Objects and object recognition

(Nature Neuroscience 2001; Cerebral Cortex 2011)

Body images (Current Biology 2014)

Numerical symbols (Nature Communications 2014)

Faces and facial expression (Neuron 2012; in preparation)



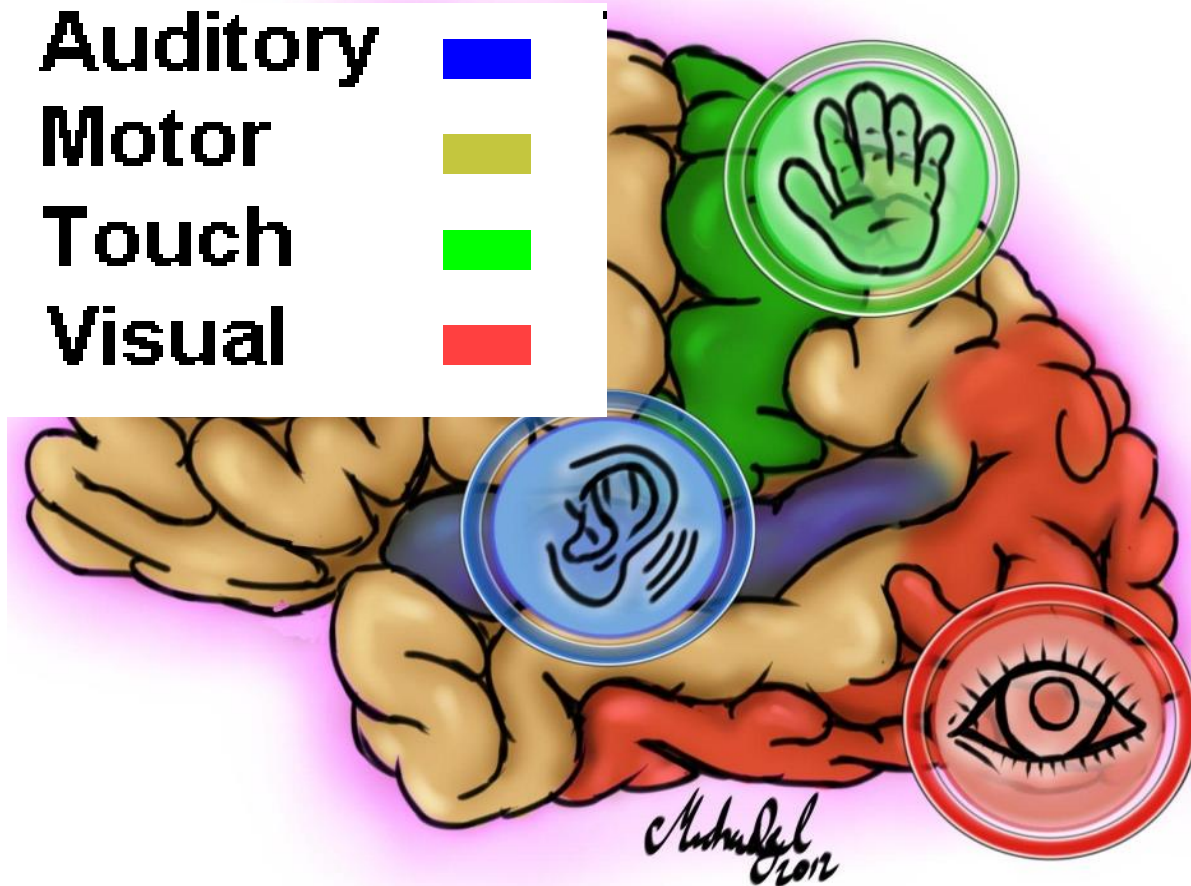
DrawMusic & MathMusic



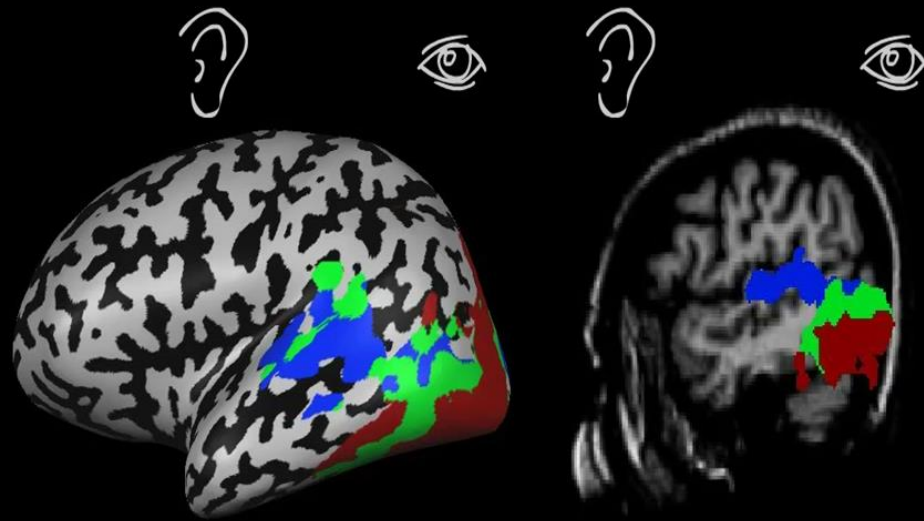
What about faces?



The Classical model: brain = sensory machine?



Before specificity: what happens to any image? Sound >> Vision



HILL



© Amedi Lab 2012

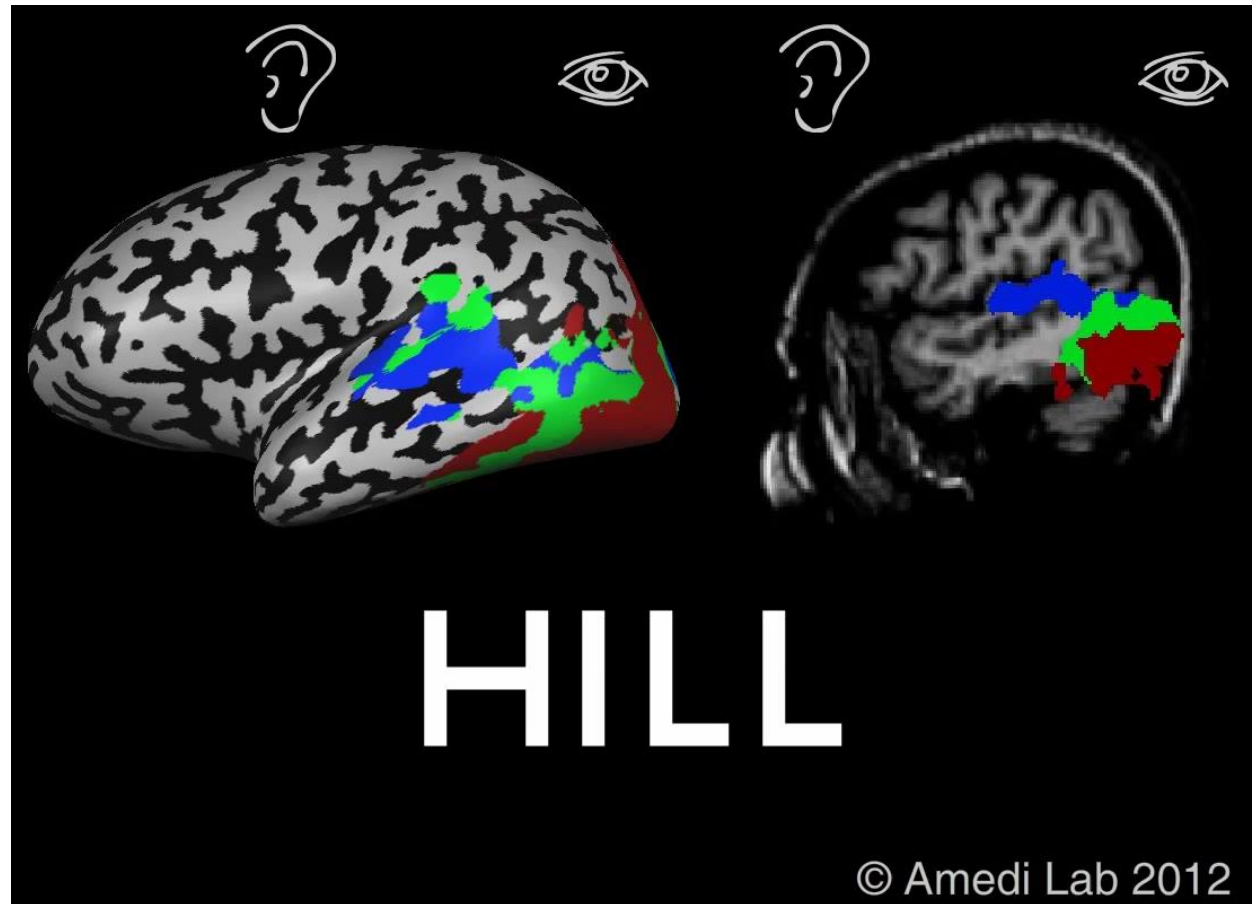
Based on Zeharia et al. *PNAS* 2012; Zeharia et al. *Journal of Neuroscience* 2015

(c) www.amedilab.com ameditab6@gmail.com

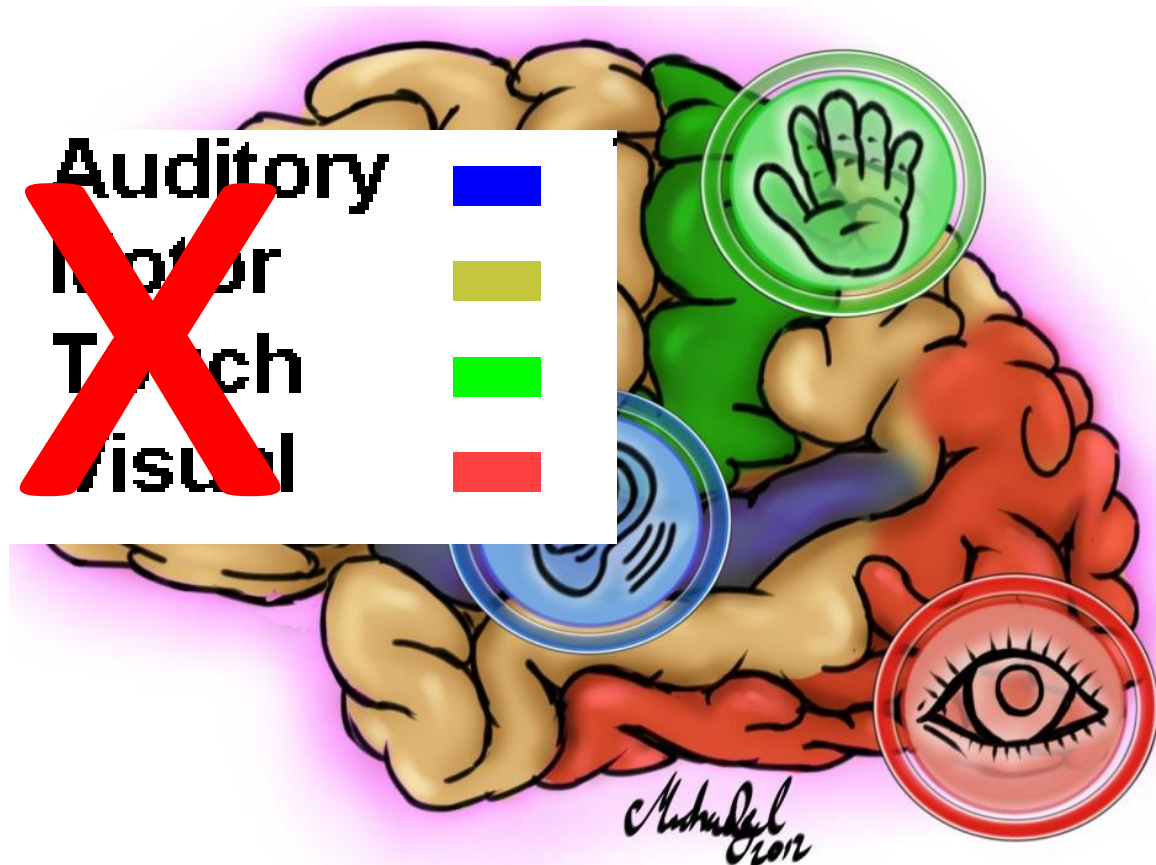
The brain turns the sounds back to vision / visual brain

Even in blind from birth.
visual
Experiences!

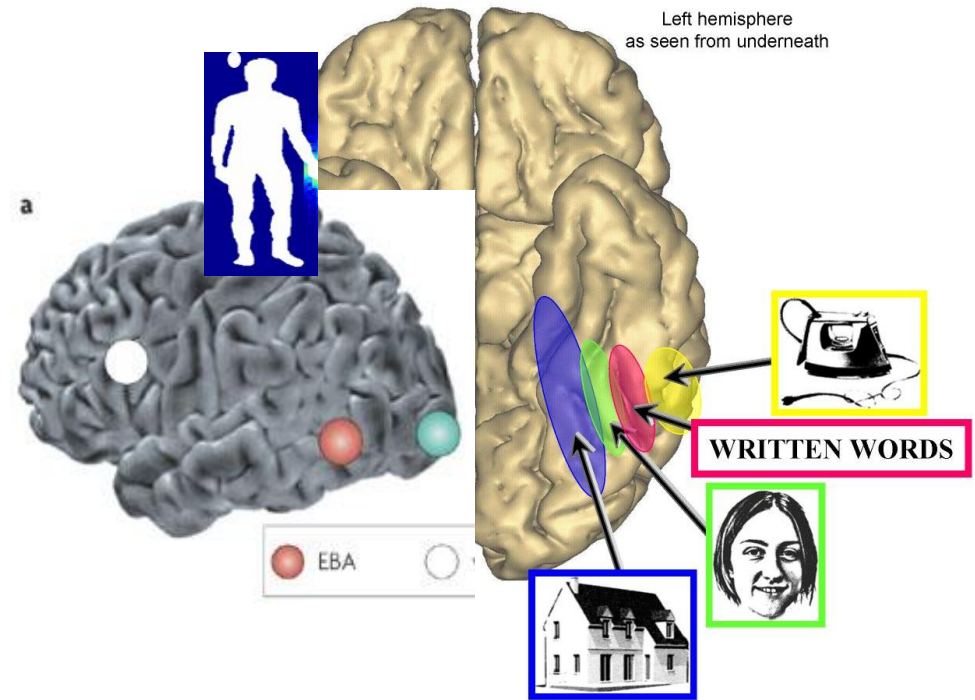
(e.g. sigalov,
maidenbaum, Amedi
Neuropsychologia
2015)



The division of labor between the senses is questionable?

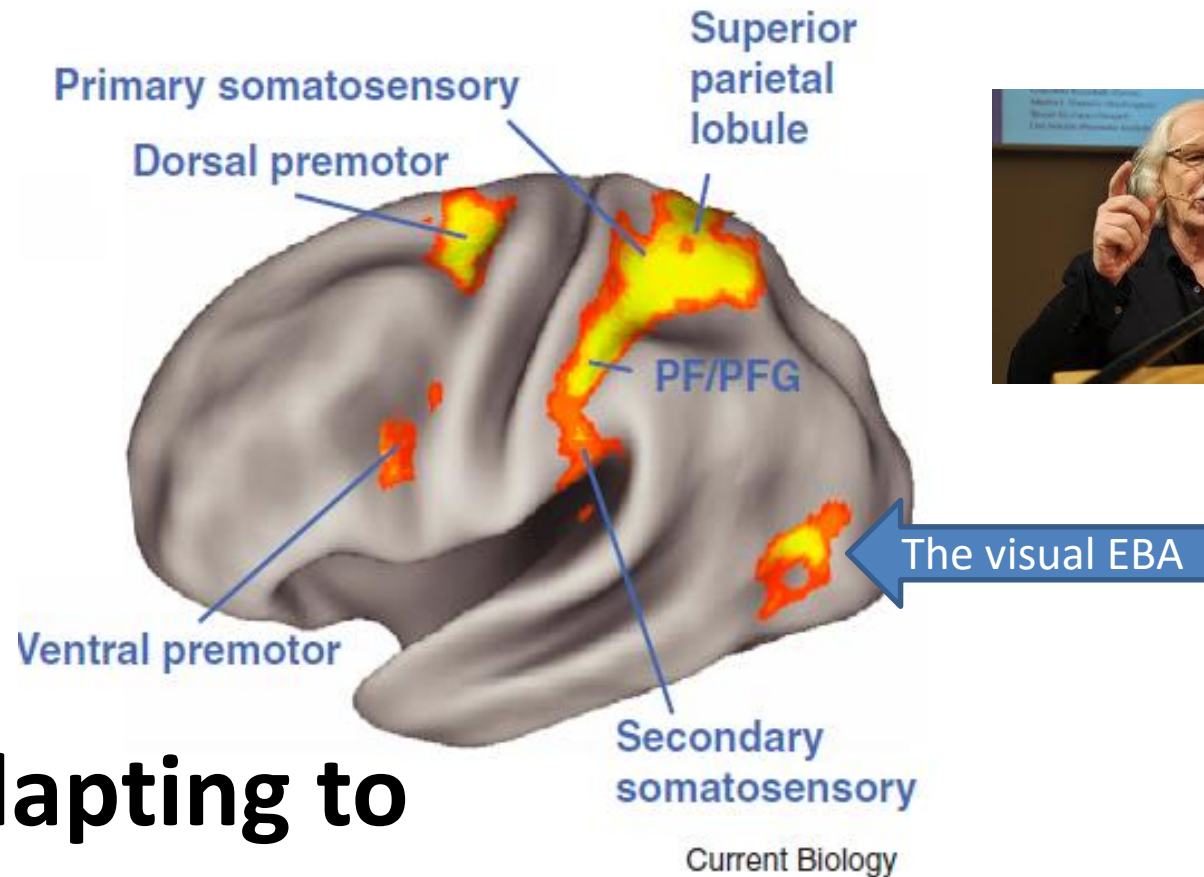


Functional specificity in the human brain: a window into the functional architecture of the mind



Adapted from Kanwisher 2010 vs. Berhmann et al. TICS 2013

Mirror system: how we learn to imitate and to understand the other!



Key in adapting to new technologies





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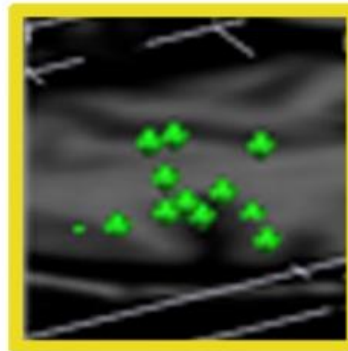
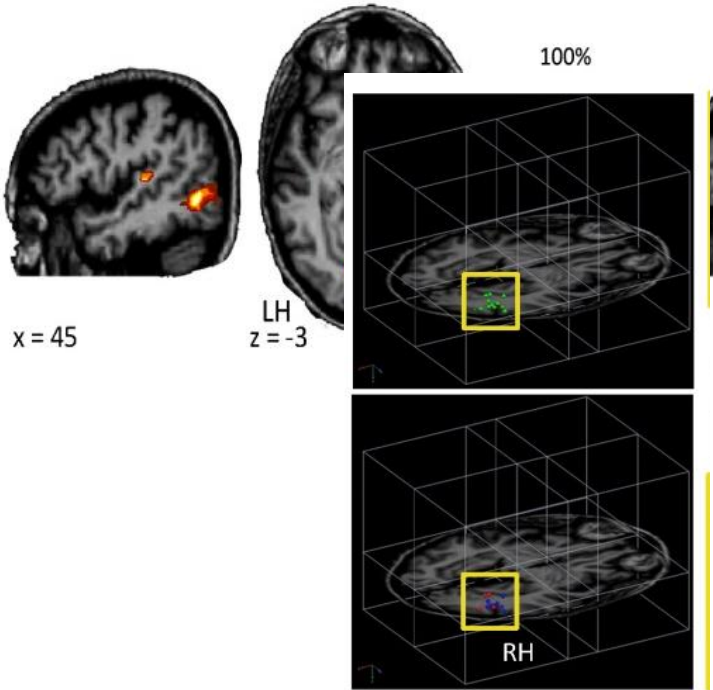
Generalization to other brain areas



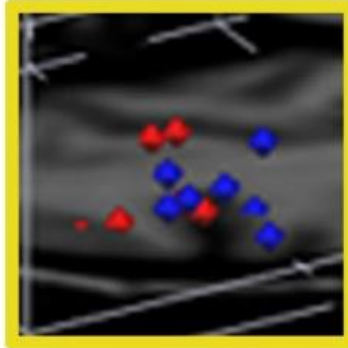
Category selectivity for body shape images in sighted and blind

B Activation for body-shapes: Inter-subject Single-subject overlap probability maps

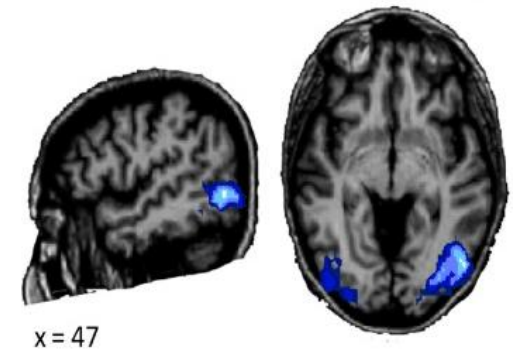
Blind (via SSD, n=7)



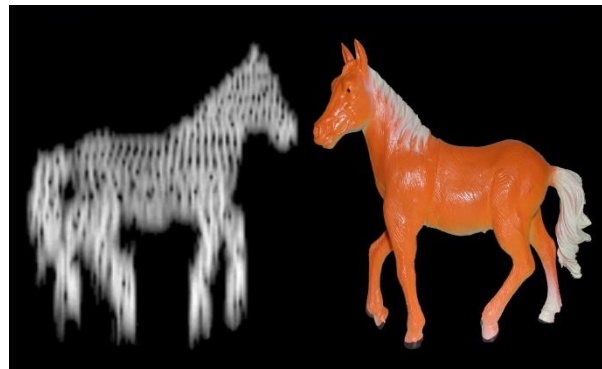
Blind
Sighted
All subjects



Blind and sighted overlap (n=14)



Visual cortex organization

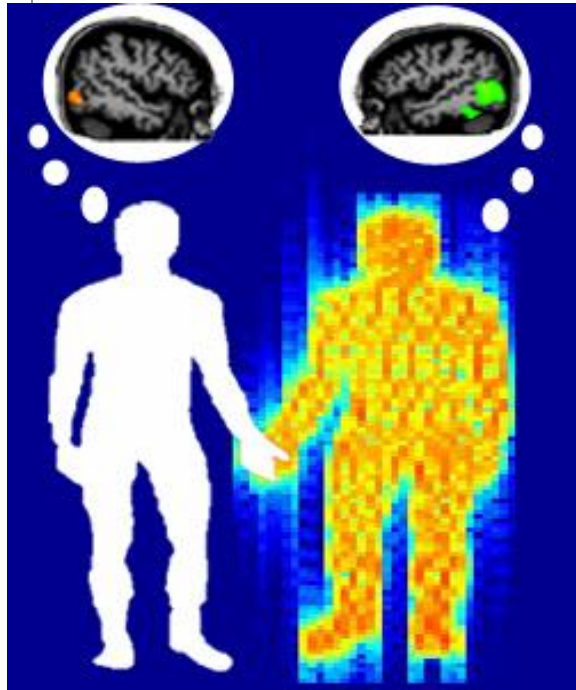


Objects and Tools in LOC;

Ventral vs. dorsal streams;
 Amedi et al. Nat. Neurosci 2001, 2007;
 CCX 2002; RNN 2010;
 Striem-Amit et al CCX 2012

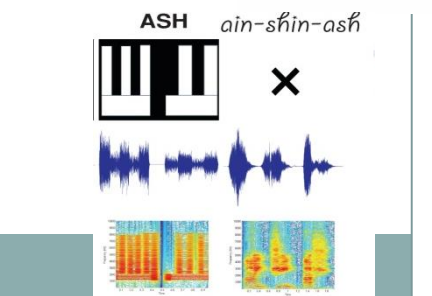
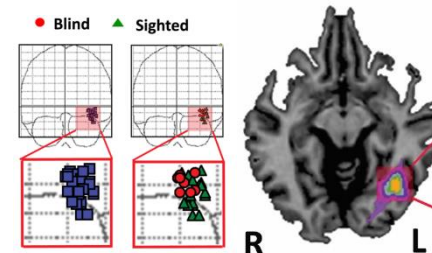
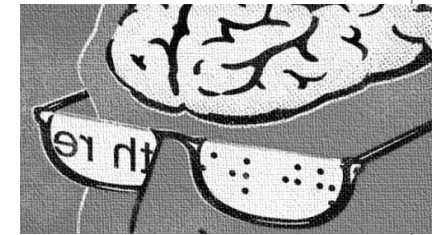
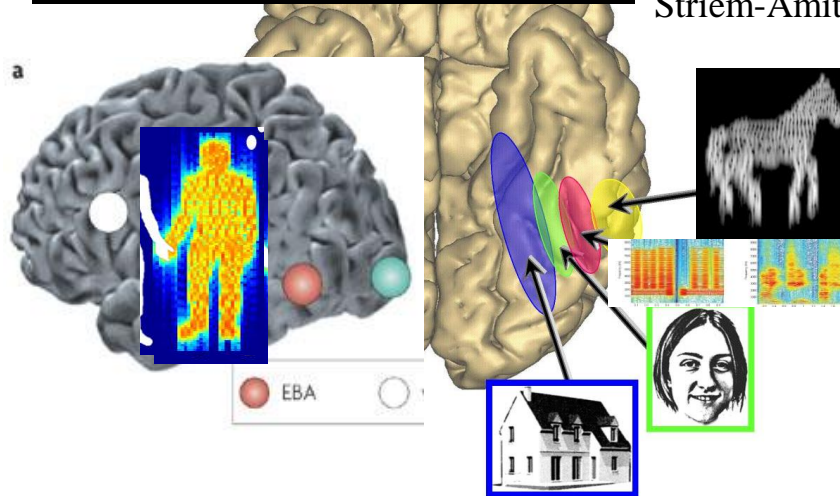
Reading in VWFA:

Reich et al Current biology 2011
 Striem-Amit et al. Neuron 2012

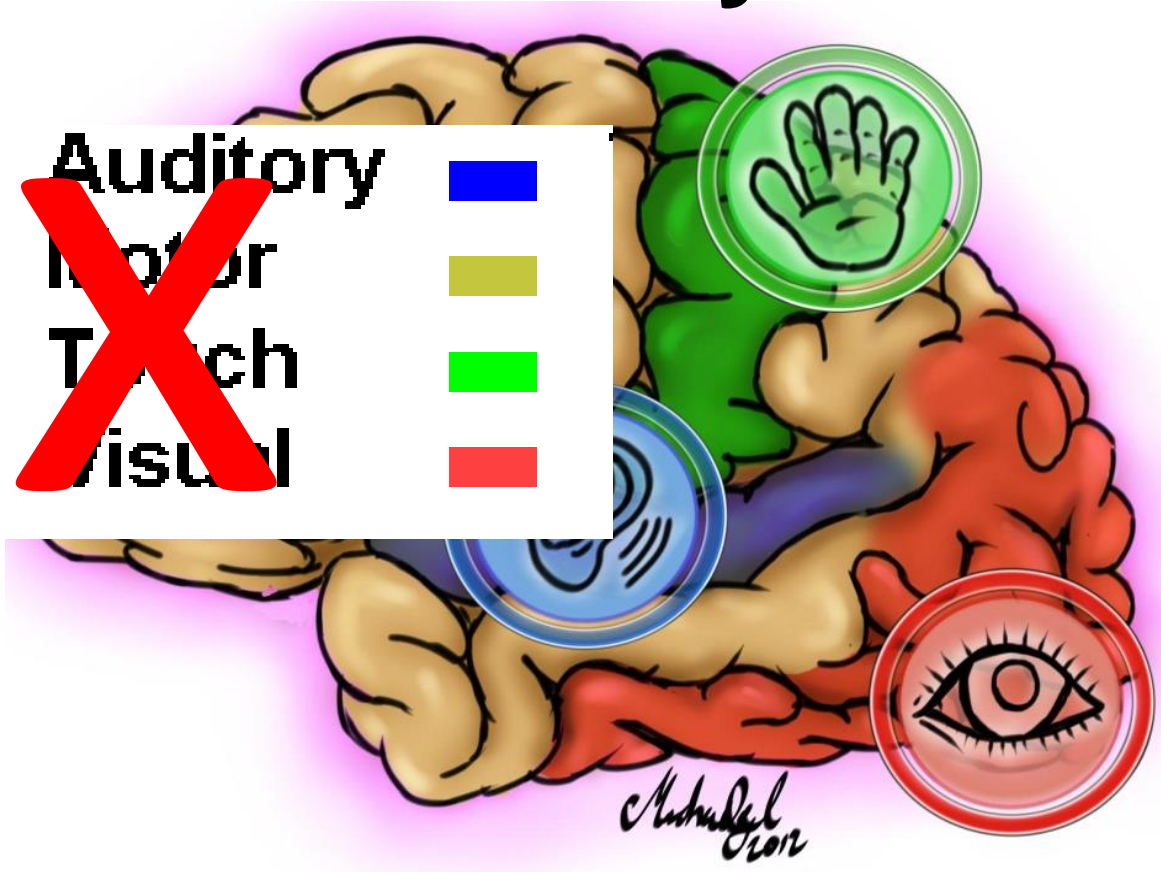


Body images and understanding of other's body postures and intentions in EBA and TPJ;

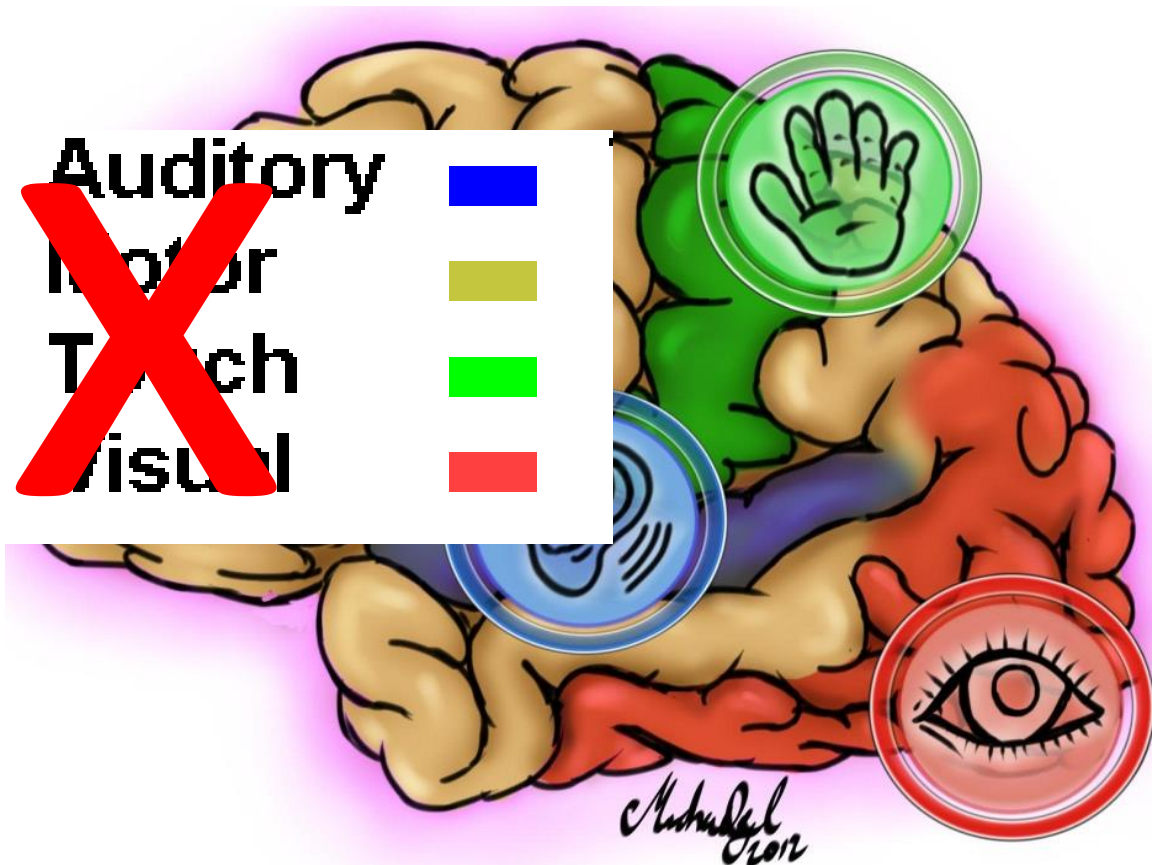
Striem-Amit & Amedi
Current Biology 2014;



Functional specialization is multisensory in nature, flexible and use some (innate?) existing connectivity

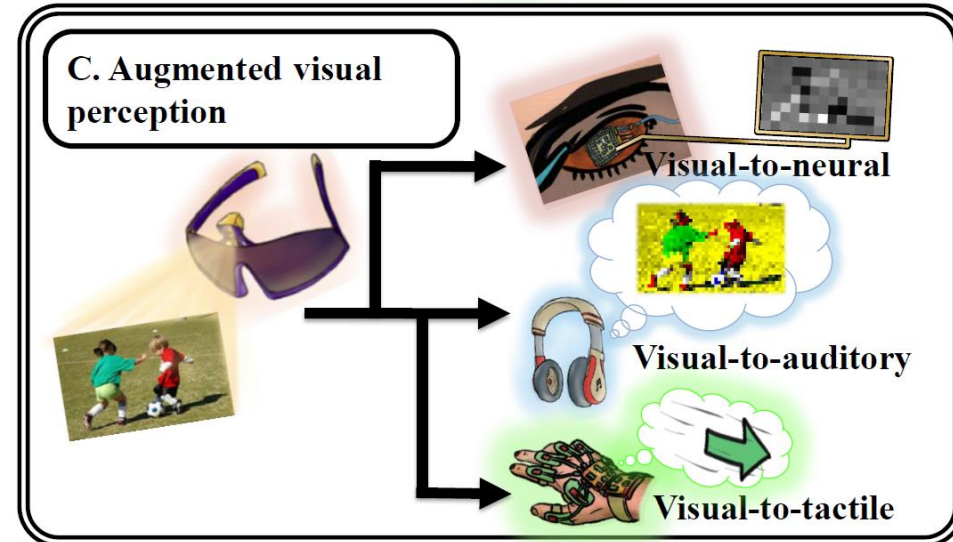
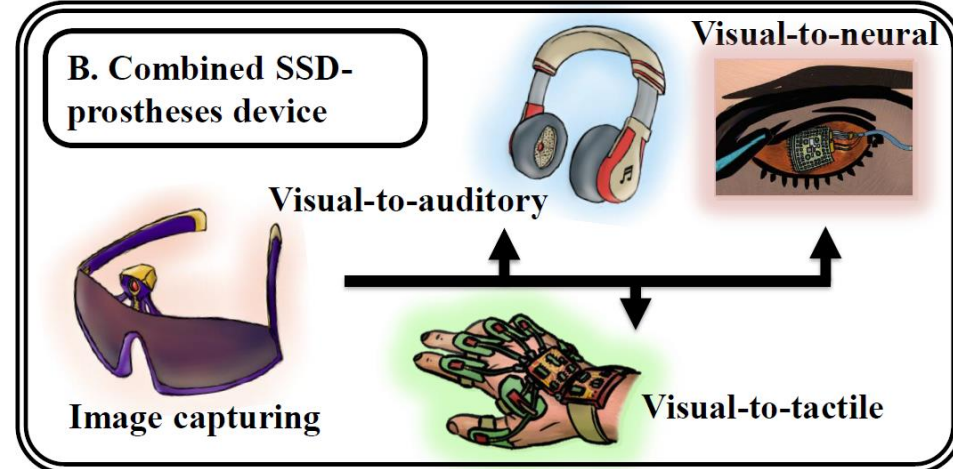


The brain is NOT a sensory machine – it is more like a behaviorally relevant sensory independent TASK MACHINE

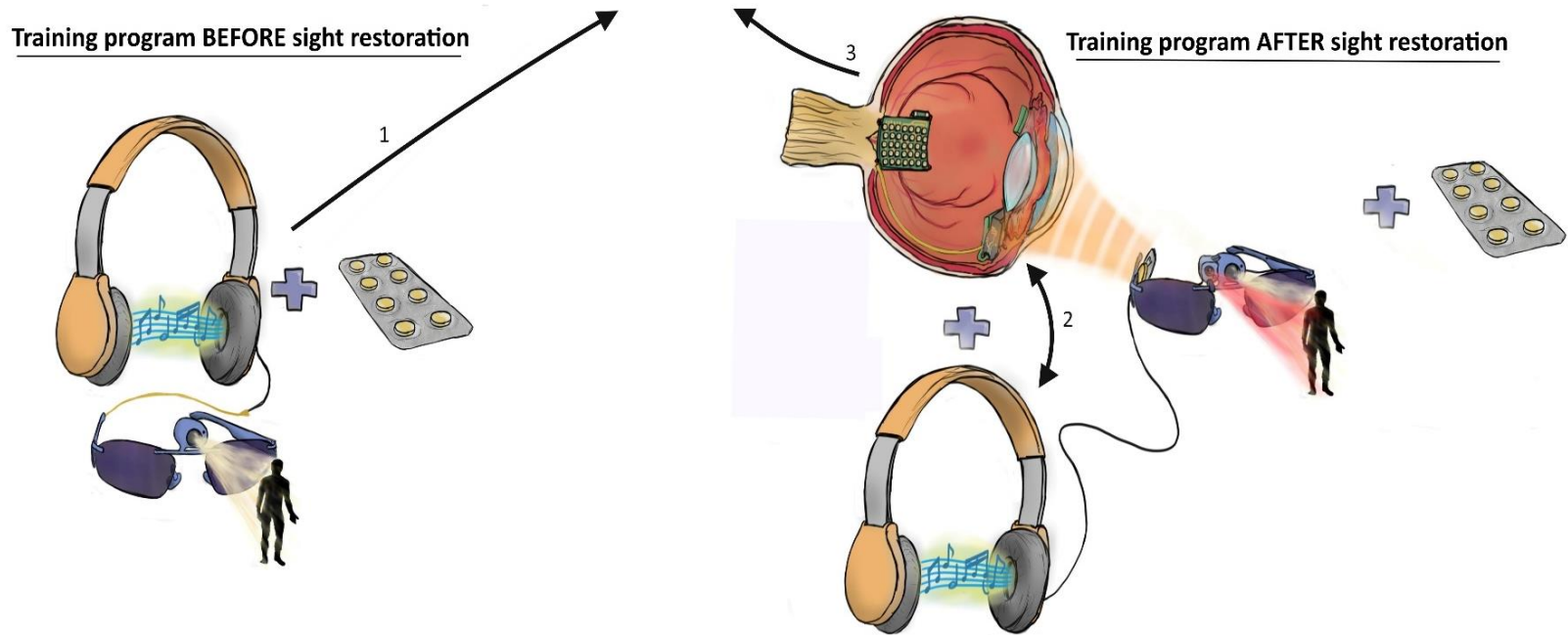


The multisensory bionic eye ERC project BrainVisionRehab (Amedi lab)

- (1) Training faster and better using SSD and Machine Vision
- (2) Increased resolution & color vision using SSDs and CV
- (3) Wider field of view
- (4) Qualia coming from prostheses but might be linked to the SSD and will increase qualia even non invasively



How can we use this for brain rehabilitation of both bionic eyes and cochlear implants (bionic ears) and computer vision



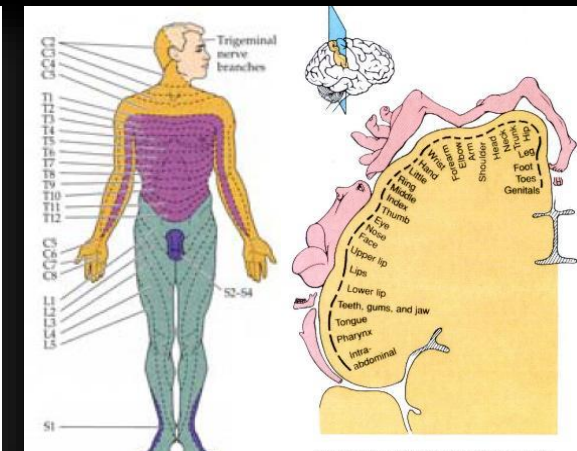
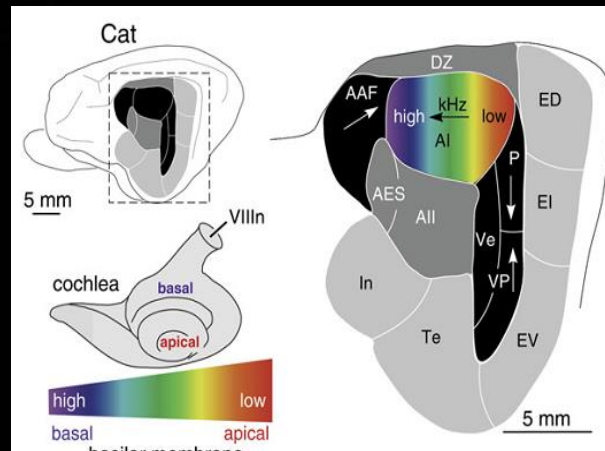
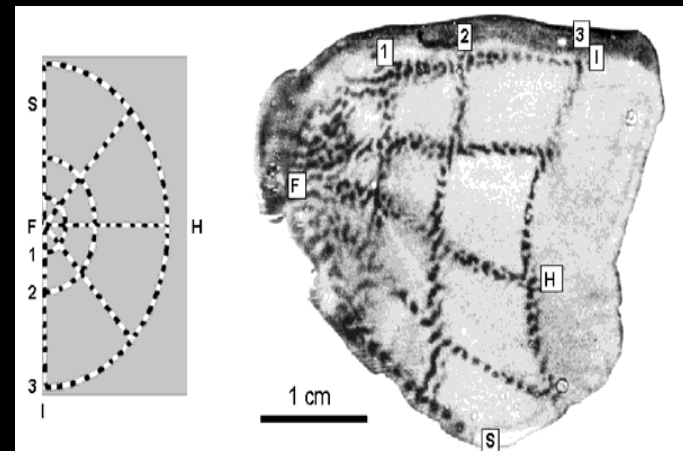
Origins of Task-specific sensory-independent brain organization in the visual and auditory systems: neuroscience evidence, open questions and clinical implications"; Hiemler, Striem-Amit & Amedi

Current Opinion in Neurobiology 2015



Introduction – the topographical brain

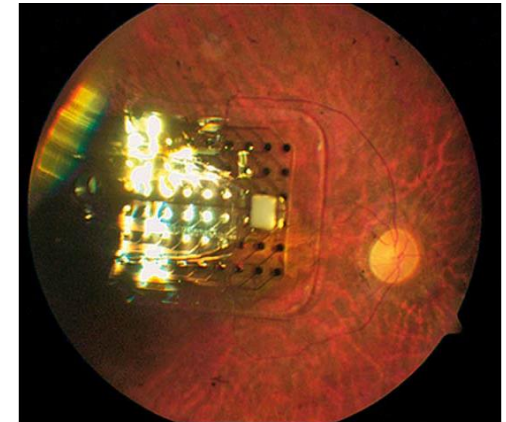
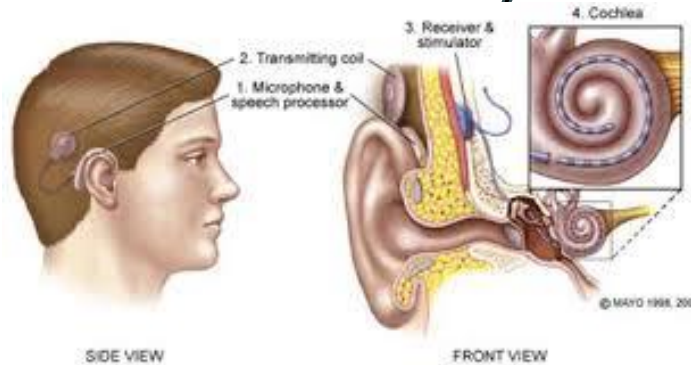
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Cyborgs – the revolution already started

Implants and the way they interact with our brain

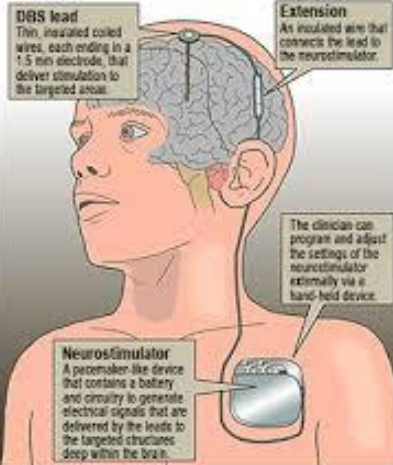
(Bionic eye; ears; arms; DBS; NewSenses vs. ReNewSenses)



Photograph by Second Sight Medical Products

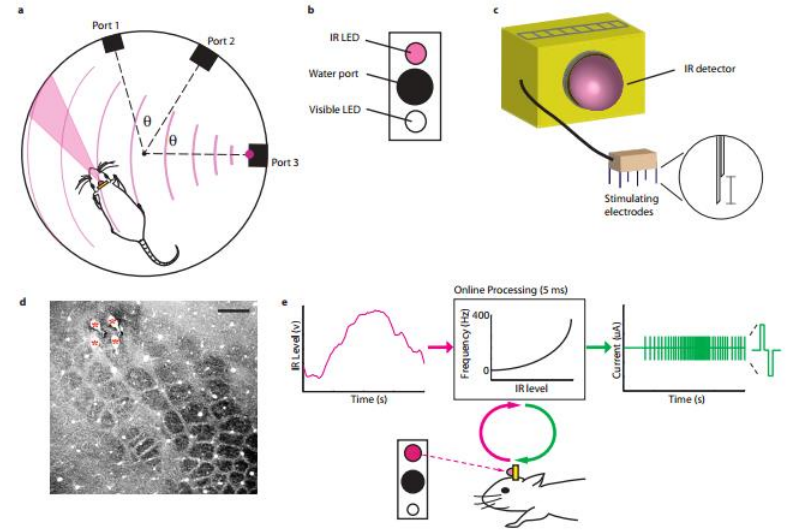
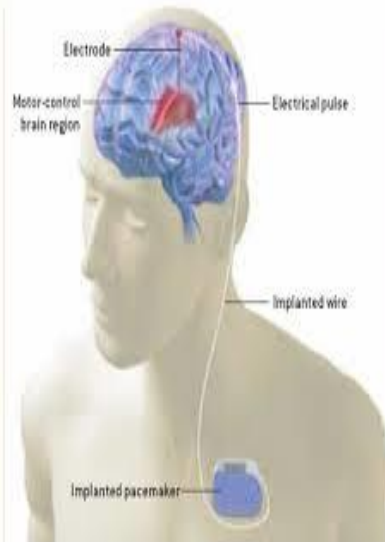
Deep brain stimulation

The Deep Brain Stimulation system is used to help control tremors and chronic movement disorders. Tiny electrodes are surgically implanted in the brain and are connected via a subcutaneous wire to a neurostimulator (or two, for some diseases) implanted under the skin near the clavicle.

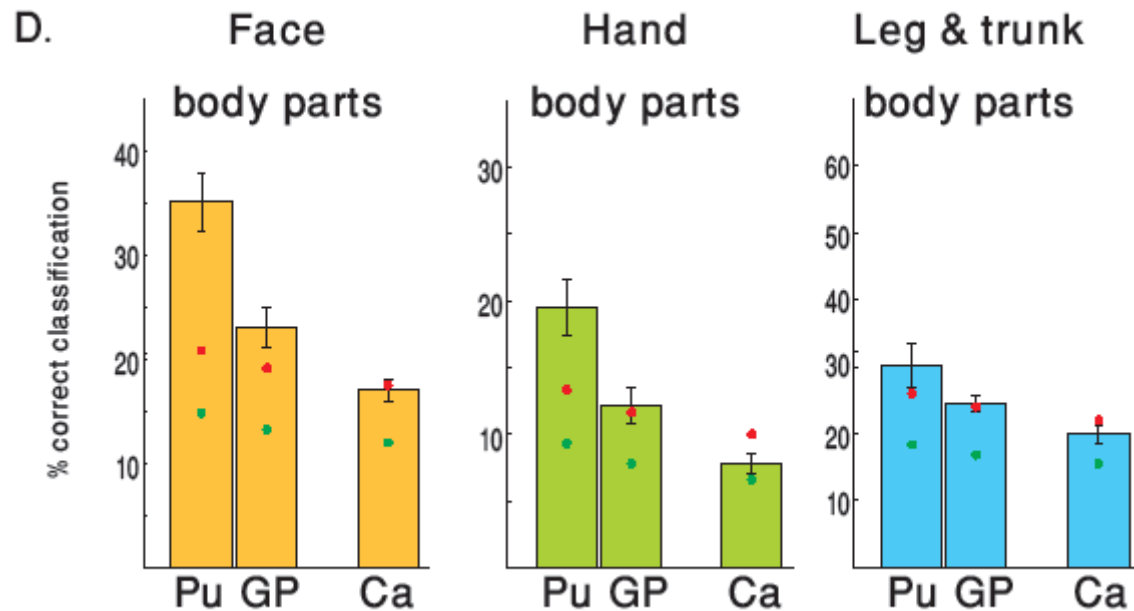


Source: Medtronic Inc.

Steve Greenberg / Star staff



How better can we decode and build the person movement & intentions based on combining info from all these maps and integrating them with prostheses?



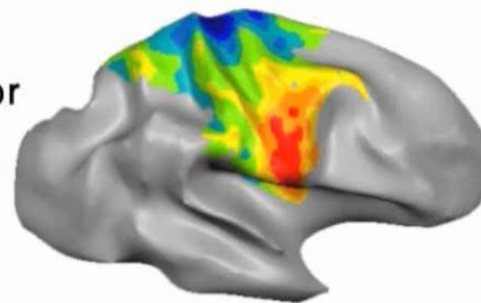
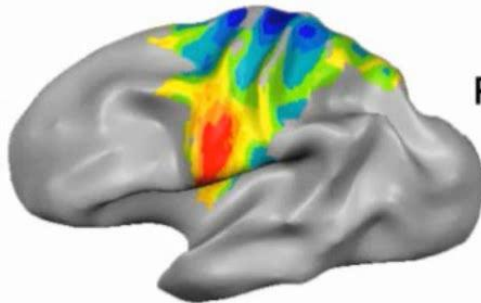
LH

RH

Anterior

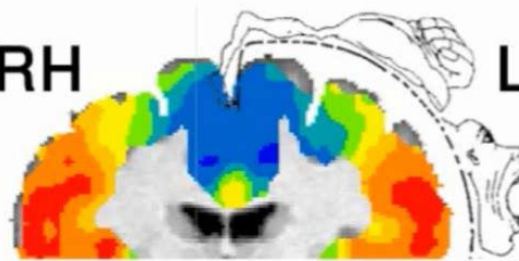
Posterior

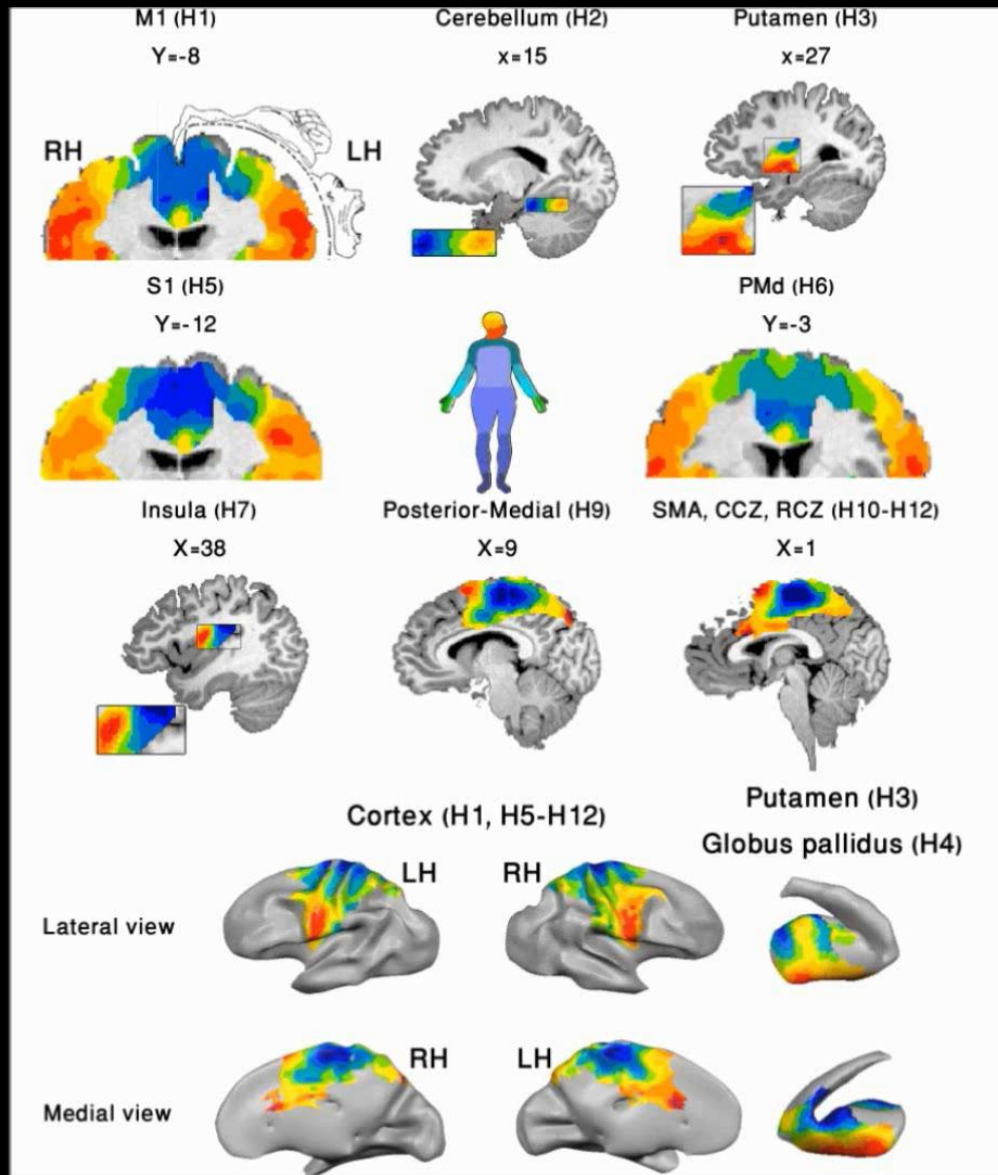
Anterior



RH

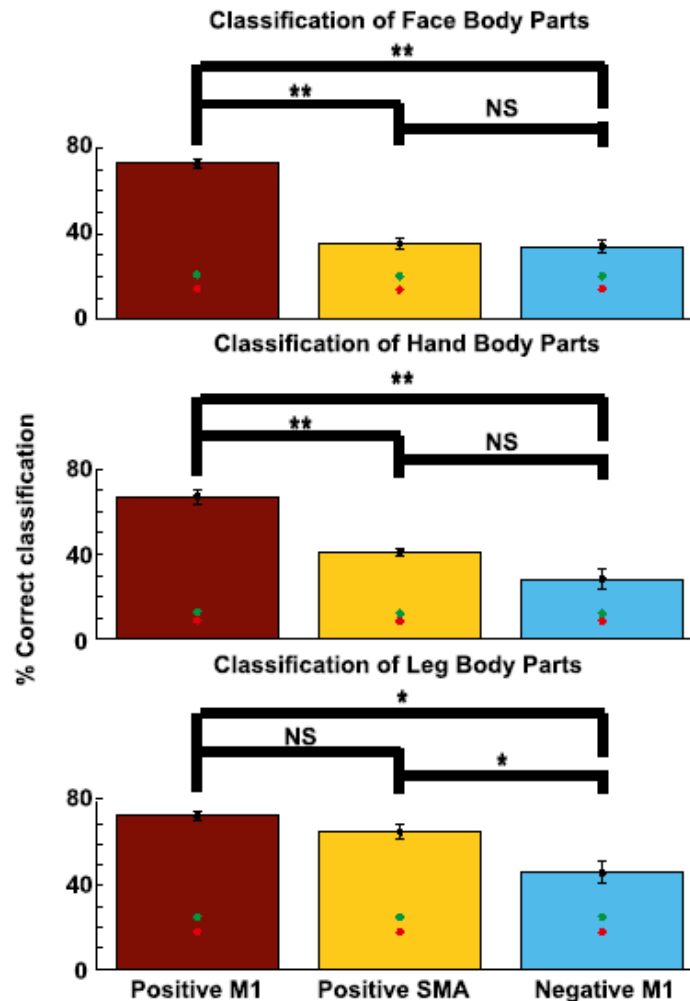
LH





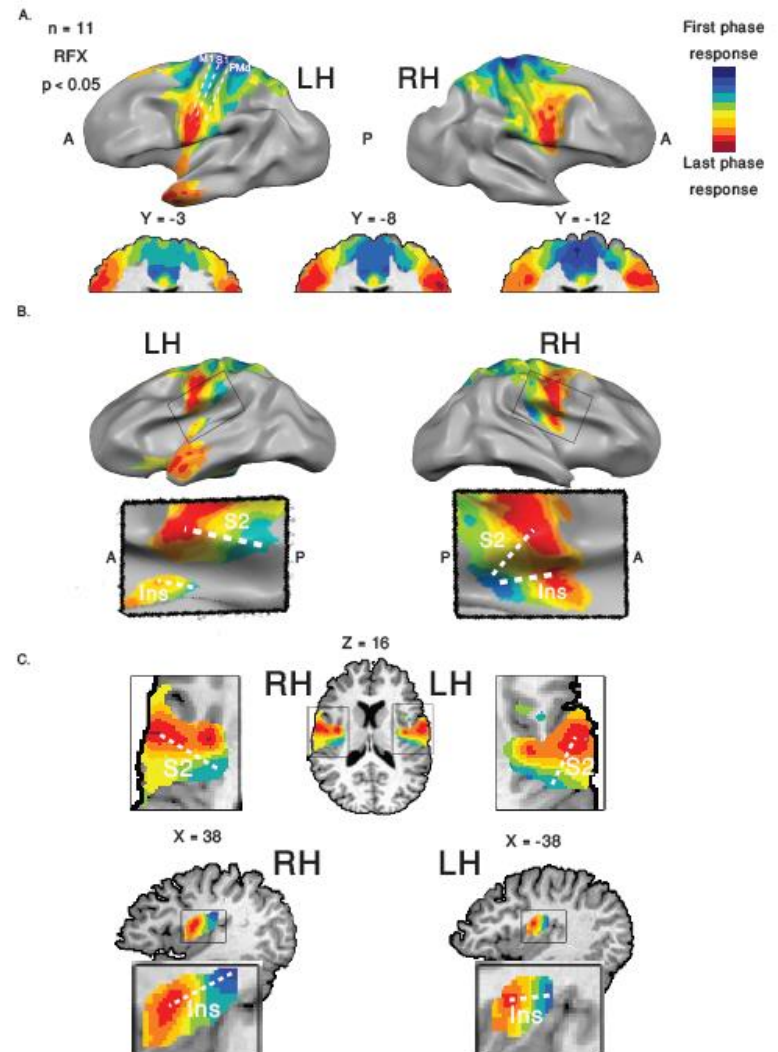
Results – M1 and SMA – SVM/machine learning of predicting any movement of a body part from brain activity

Zeharia *et al.*
Proceedings of the National Academy of Science USA
PNAS, 2012

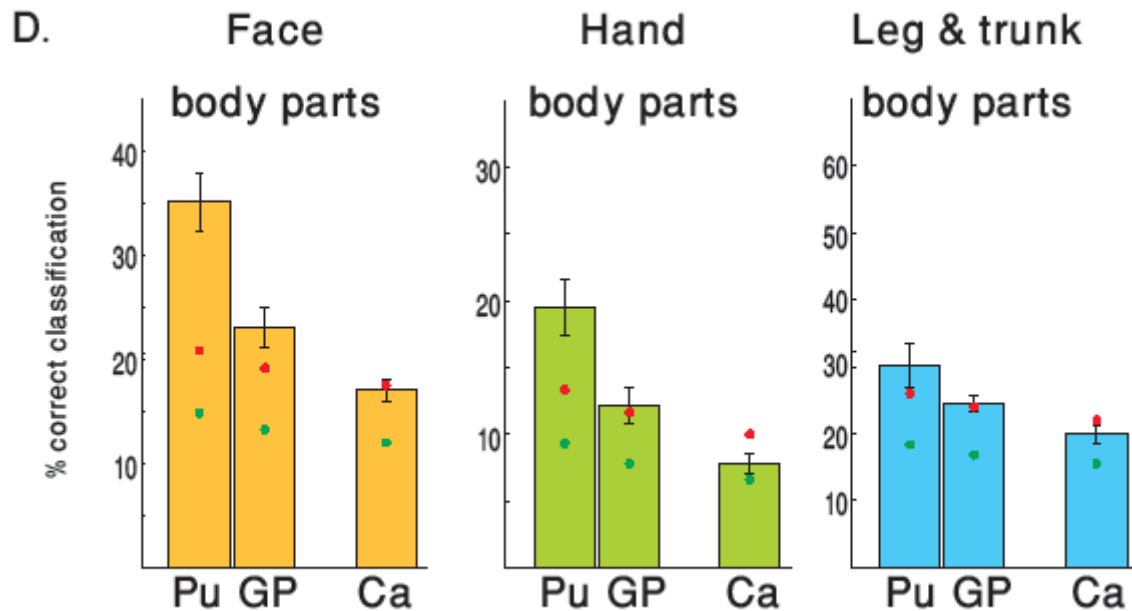


Results – 12 homunculi most of them novel (Amedi lab; Journal of Neuroscience 2015)

- **M1, S1, PMd** – dorsal-to-ventral, medial-to-lateral, toes-to-tongue gradient.
- **S2** - posterior-to-anterior, medial-to-lateral, toes-to-tongue gradient.
- **Posterior dorsal insula** - posterior-to-anterior, toes-to-tongue gradient.

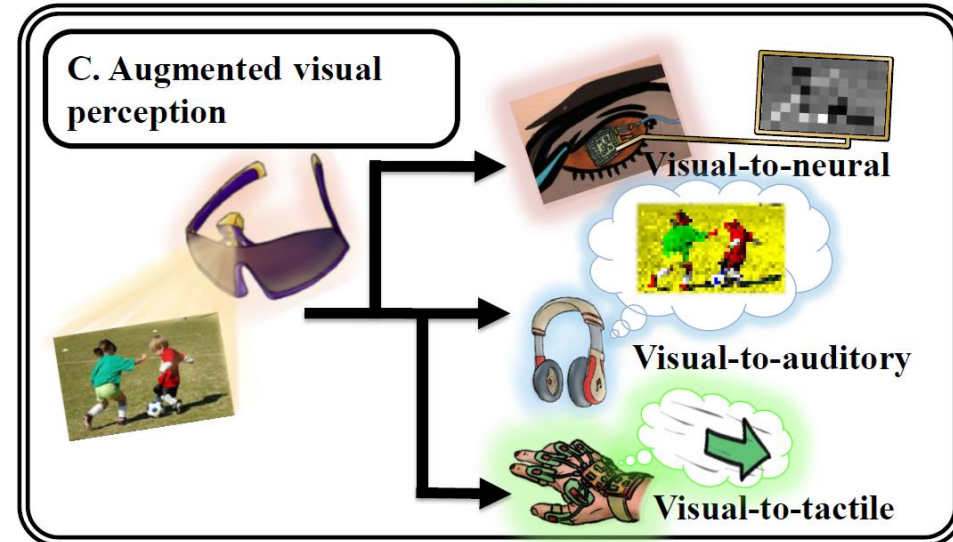
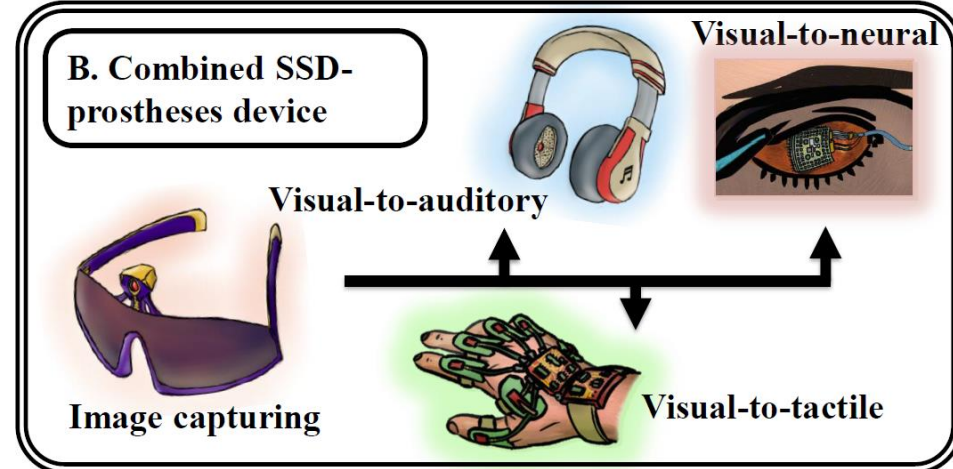


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The multisensory bionic eye ERC project BrainVisionRehab (Amedi lab)

- (1) Training faster and better using SSD and Machine Vision
- (2) Increased resolution & color vision using SSDs and CV
- (3) Wider field of view
- (4) Qualia coming from prostheses but might be linked to the SSD and will increase qualia even non invasively



Task switching plasticity

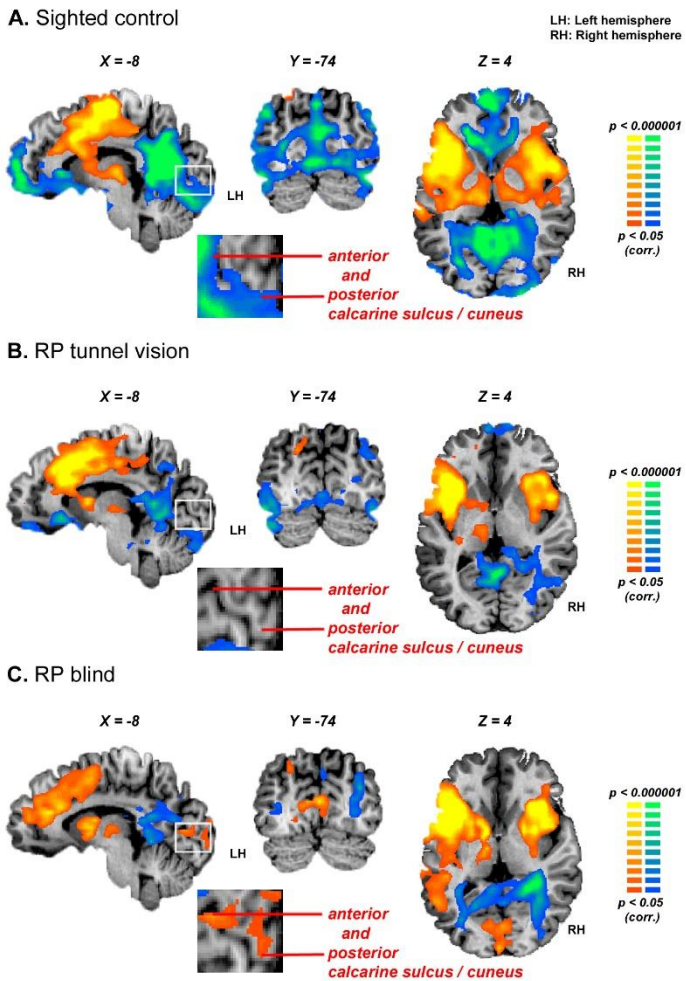


- **In the congenitally blind, language processing involves visual areas.**
- **In the case of normal visual development however, it remains unclear whether later visual loss induces interactions between the language and visual areas.**
- **This study compared the resting-state functional connectivity (FC) of retinotopic and language areas in two unique groups of late visually deprived subjects: (1) blind individuals suffering from retinitis pigmentosa (RP), (2) RP subjects without a visual periphery but with preserved central “tunnel vision”, both of whom were contrasted with sighted controls**

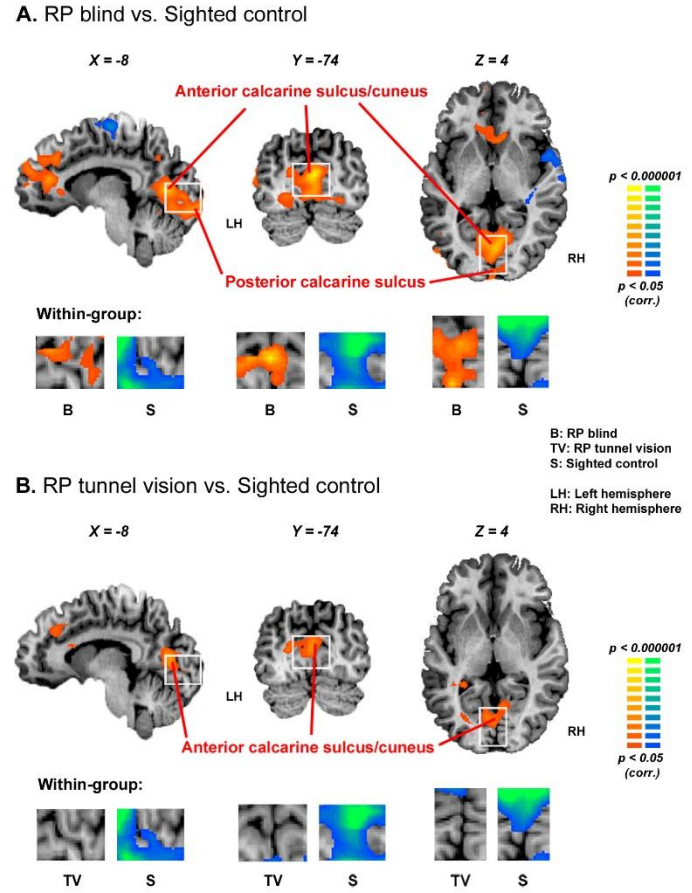
Task switching plasticity



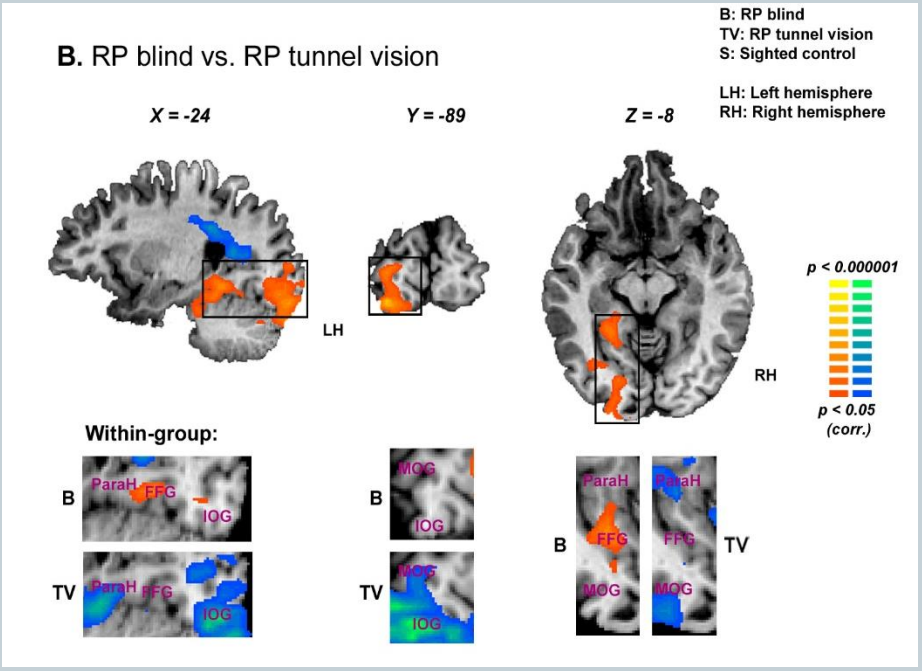
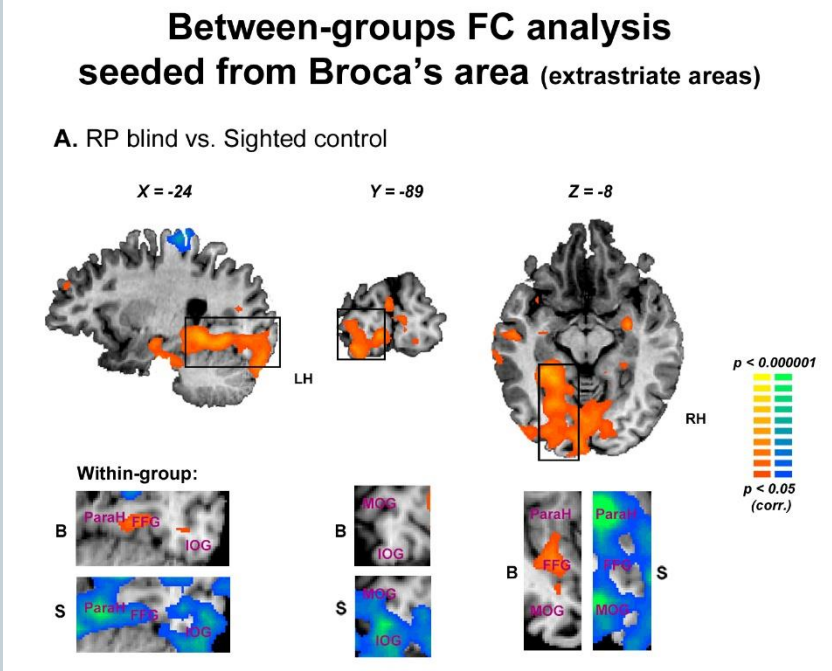
Within-group FC analysis seeded from Broca's area (calcarine sulcus/cuneus)



Between-groups FC analysis seeded from Broca's area (calcarine sulcus/cuneus)



Task switching plasticity



Task switching plasticity



- **The results showed increased FC between Broca's area and the visually deprived areas in the peripheral V1 for individuals with tunnel vision, and both the peripheral and central V1 for blind individuals.**
- **These findings suggest that FC can develop in the adult brain between the visual and language systems in the completely and partially blind. These changes start in the deprived areas and increase in size (involving both foveal and peripheral V1) and strength (from negative to positive FC) as the disease and sensory deprivation progress.**
- **These observations support the claim that functional connectivity between remote systems that perform completely different tasks can change in the adult brain in cases of total and even partial visual deprivation.**



Visit us at (Amedi lab)

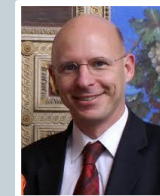
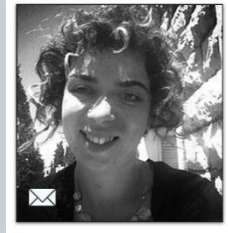
www.BrainVisionRehab.com

www.ReNewSenses.com



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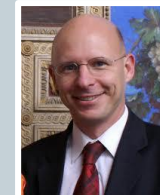
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