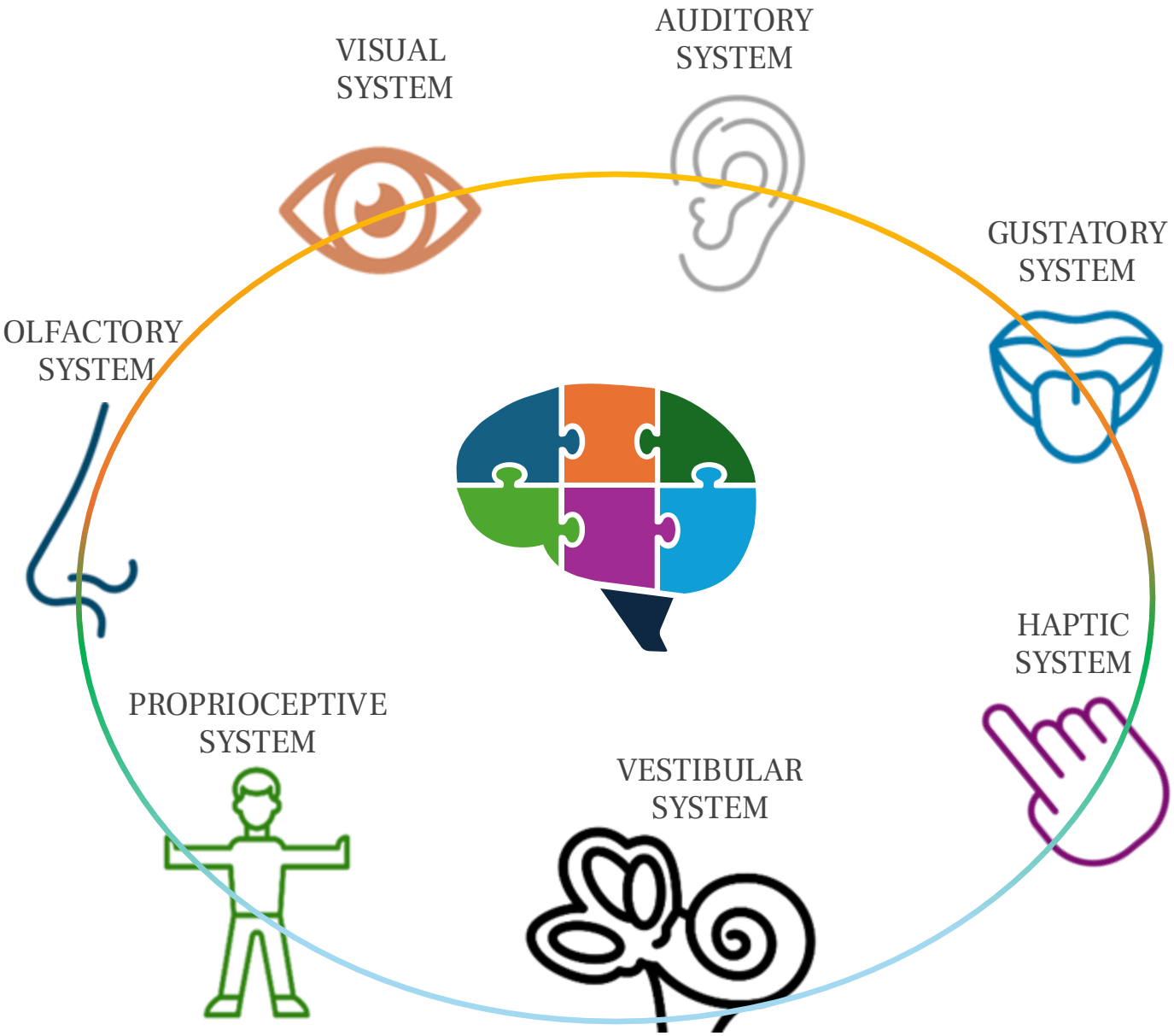
Multisensory integration and New Technological Applications in Children with visual impairment

Helene Vitali

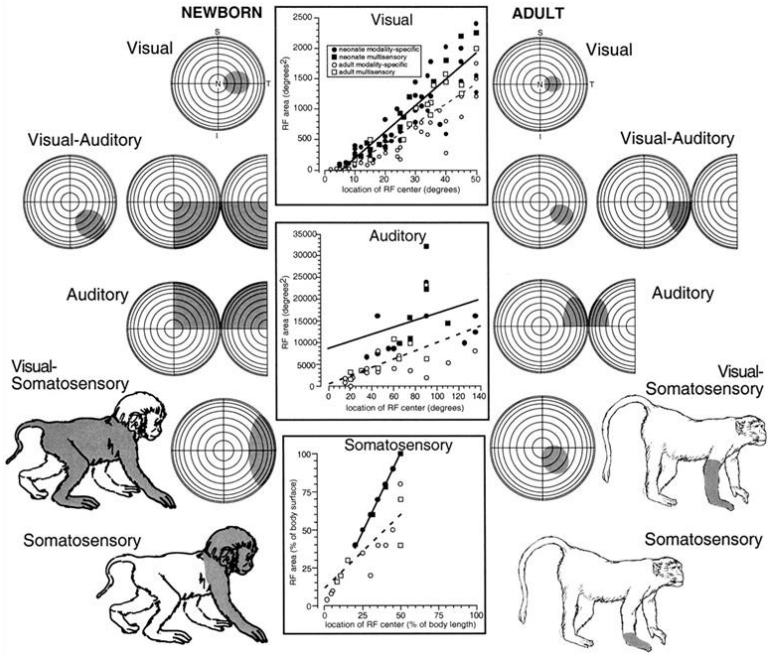
Istituto Italiano di Tecnologia (IIT), Genoa, Italy

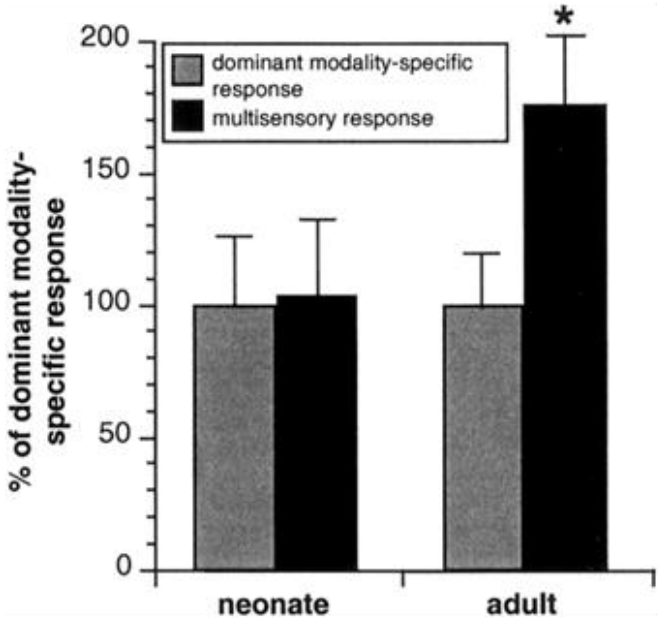
MULTISENSORY INTEGRATION



Multisensory neurons are present in newborn monkeys, but they *acquire* their spatially-specific multimodal properties during the first few months of life in an experience-dependent manner

(e.g. Wallace and Stein, 2001).

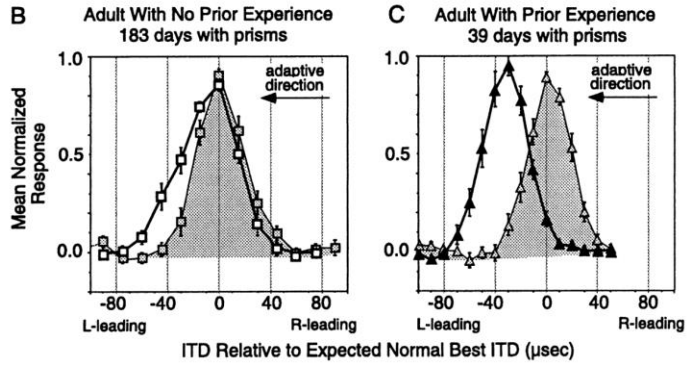




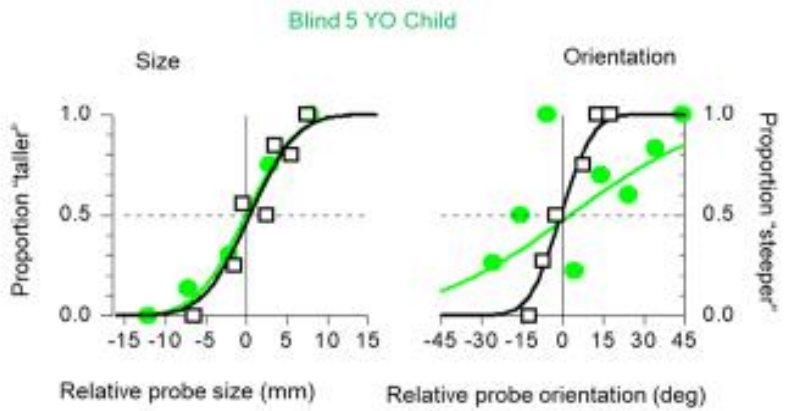
Development of multisensory abilities depends on early perceptual experiences

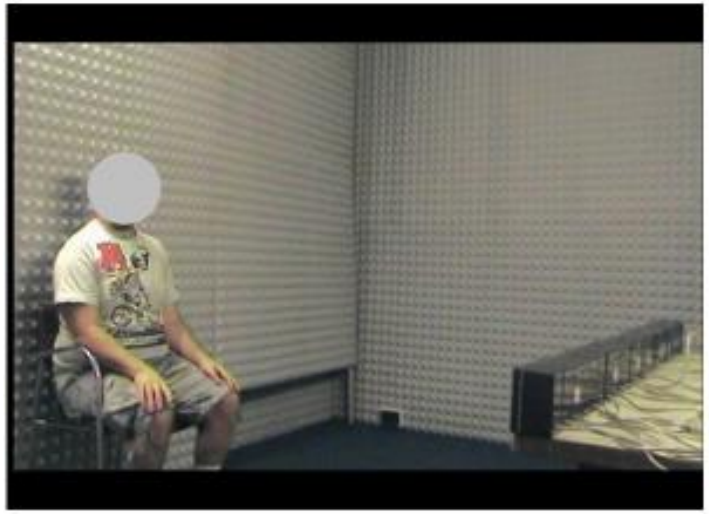
Cross-sensory calibration theory

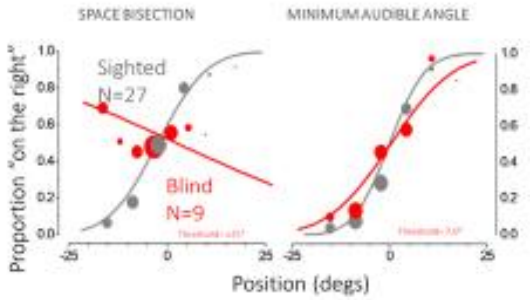
Visual experience is crucial for spatial auditory skills



Knudsen & Knudsen 1989

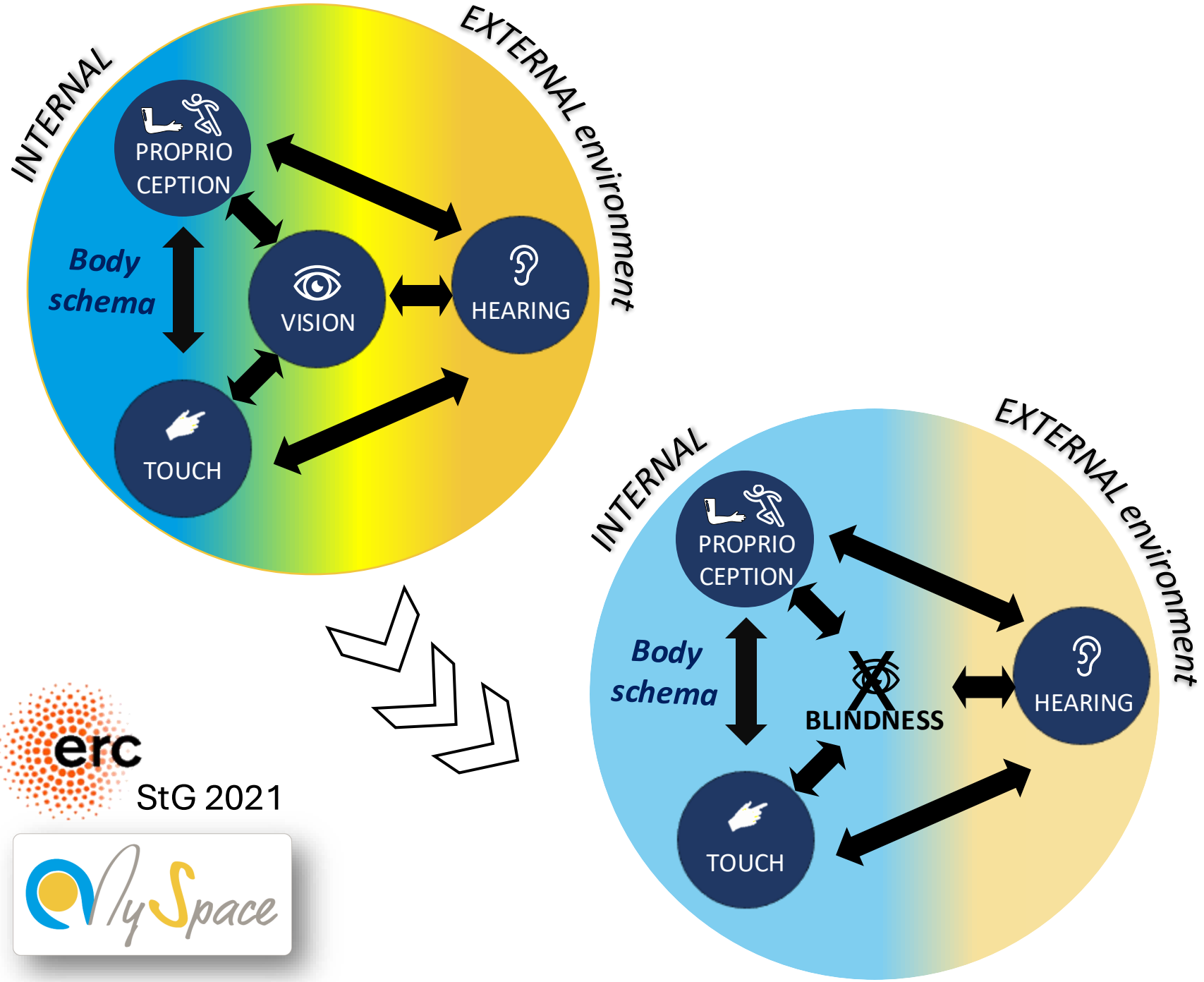






Gori et al., 2008; Gori et al., 2010, Cuturi & Gori 2017; Gori et al., 2014; Gori et al., 2016

How does multisensory integration develop when vision is missing?



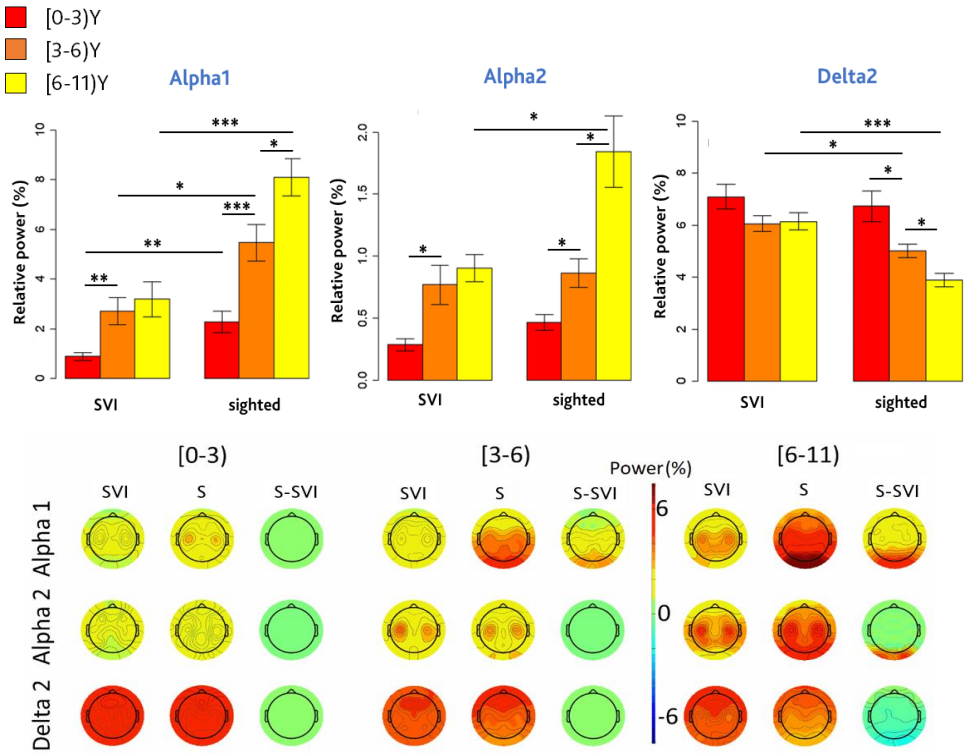
erc StG 2021

MySpace

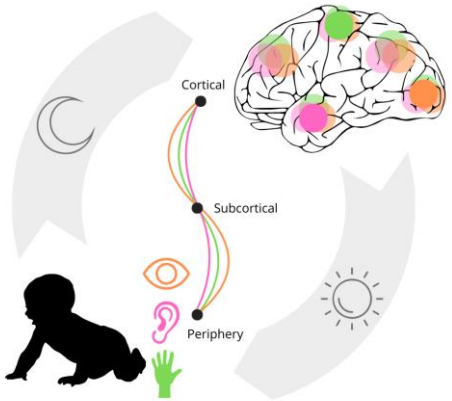
Brain and Multisensory Development

	• **Alpha activity** • **Sleep spindle activity**	• **Alpha activity** • **Sleep spindle activity**	• **Alpha activity**
	• Cross-hand tactile localization • Left-right audiotactile localization	• AV motion prediction	• Audio-tactile ventriloquist • Audio-tactile TBW • Audio-tactile Rubber Hand Illusion
	• Cross-hand tactile localization • Left-right audiotactile localization	• AV localization	• Spatial auditory oddball

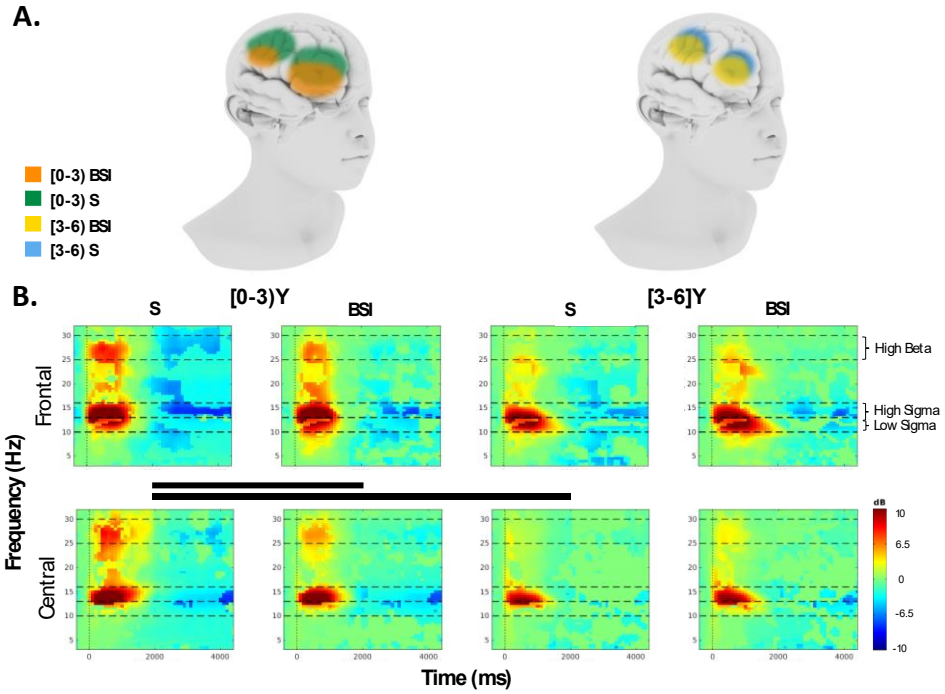
Wakefulness



Campus et al., 2021. Dev. Cog. Neuro.



Sleep

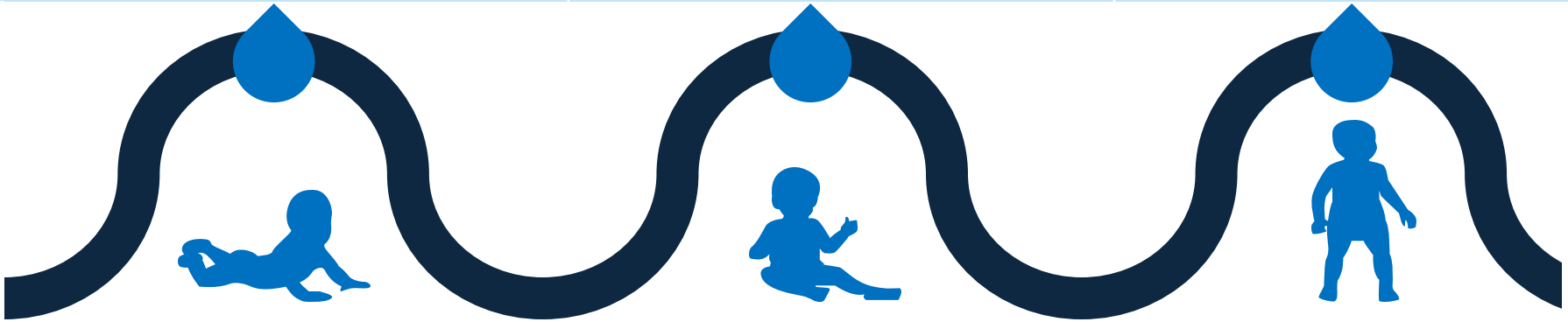


Vitali et al., 2024, Neuroimage

Perceptual clinical index under 3yo

Brain and Multisensory Development

• ~ = alpha activity • ↓Sleep spindle activity • Associated with perceptual index	• ↓ Alpha activity • ↓ Sleep spindle activity • Associated with motor disfunction	• ↓ Alpha activity • Associated with motor disfunction



Brain and Multisensory Development

	• Alpha activity • Sleep spindle activity	• Alpha activity • Sleep spindle activity	• Alpha activity
	• **Cross-hand tactile localization** • **Left-right audiotactile localization**	• AV motion prediction	• Audio-tactile ventriloquist • Audio-tactile TBW • Audio-tactile Rubber Hand Illusion
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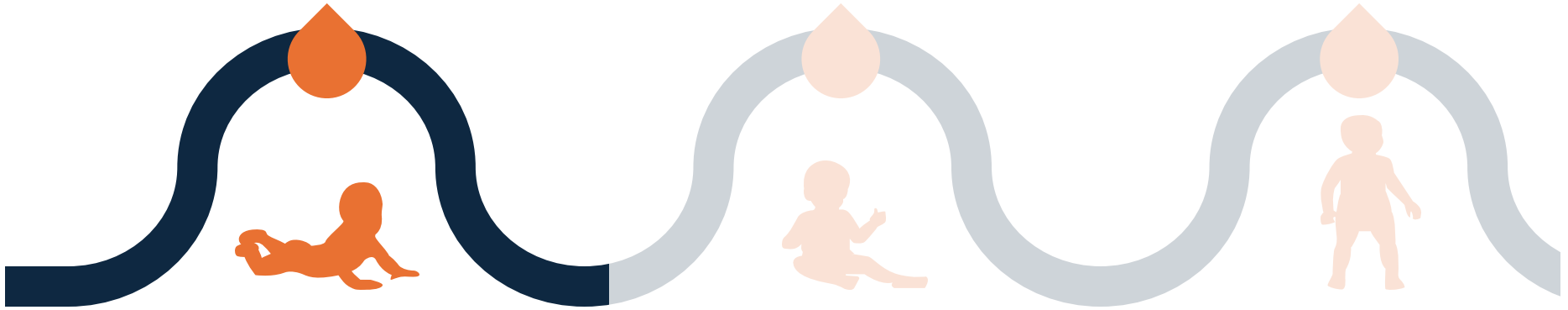
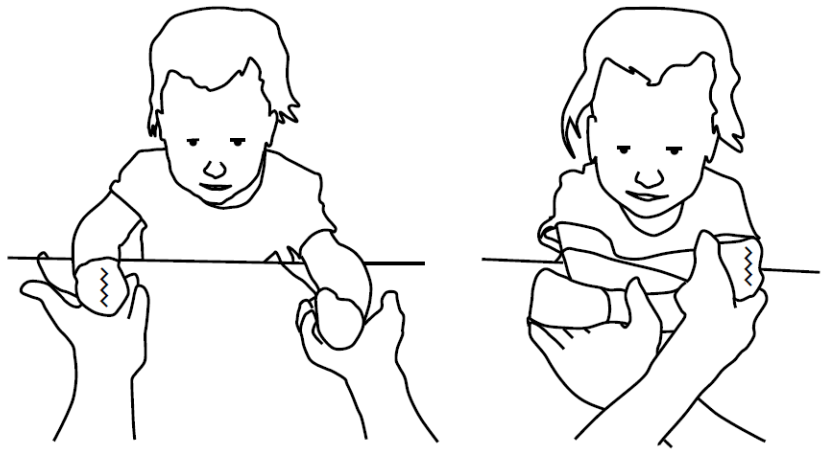
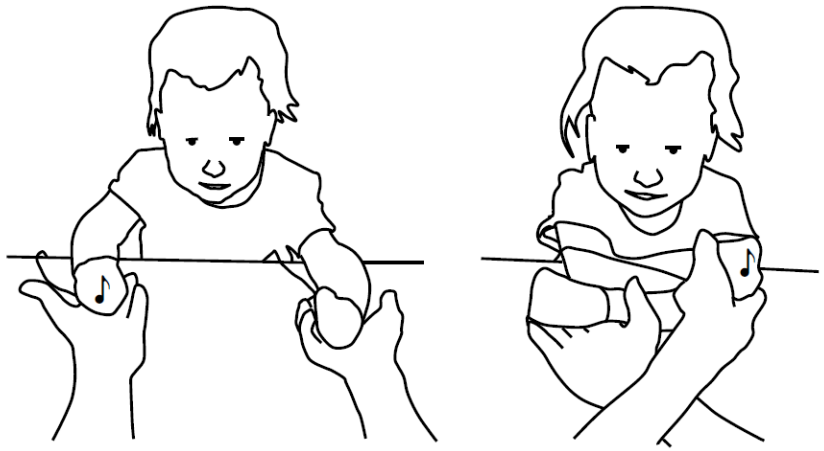


A Tactile only

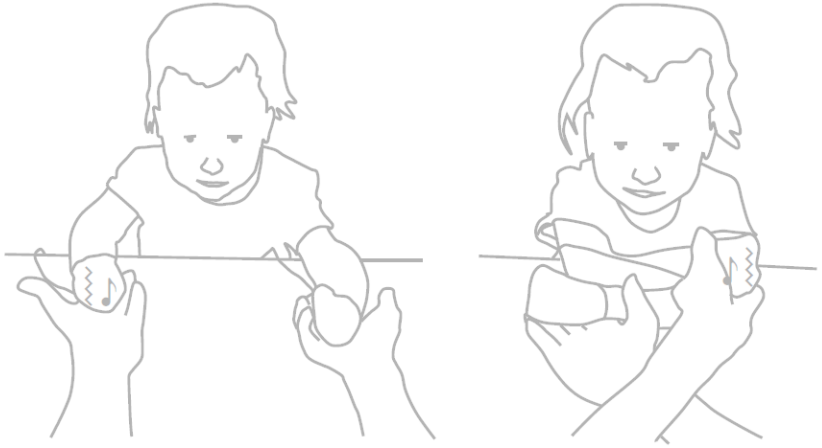


B Auditory only



♪ = Auditory stimulus
≀ = Tactile stimulus

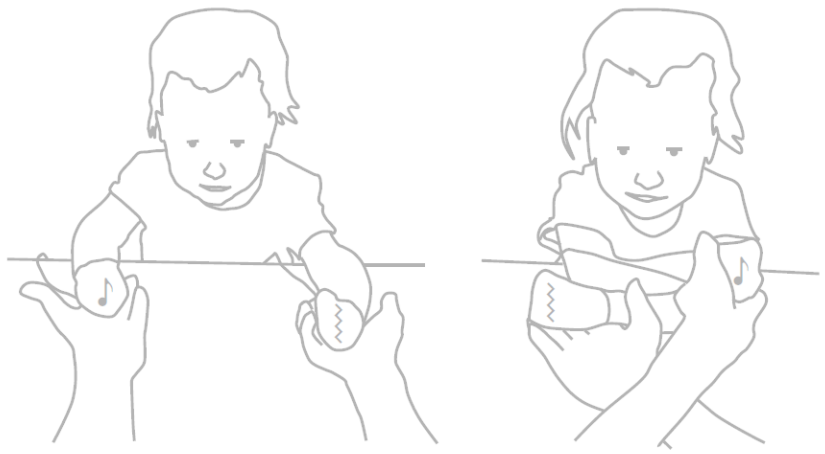
C Audiotactile congruent



Uncrossed-hands

Crossed-hands

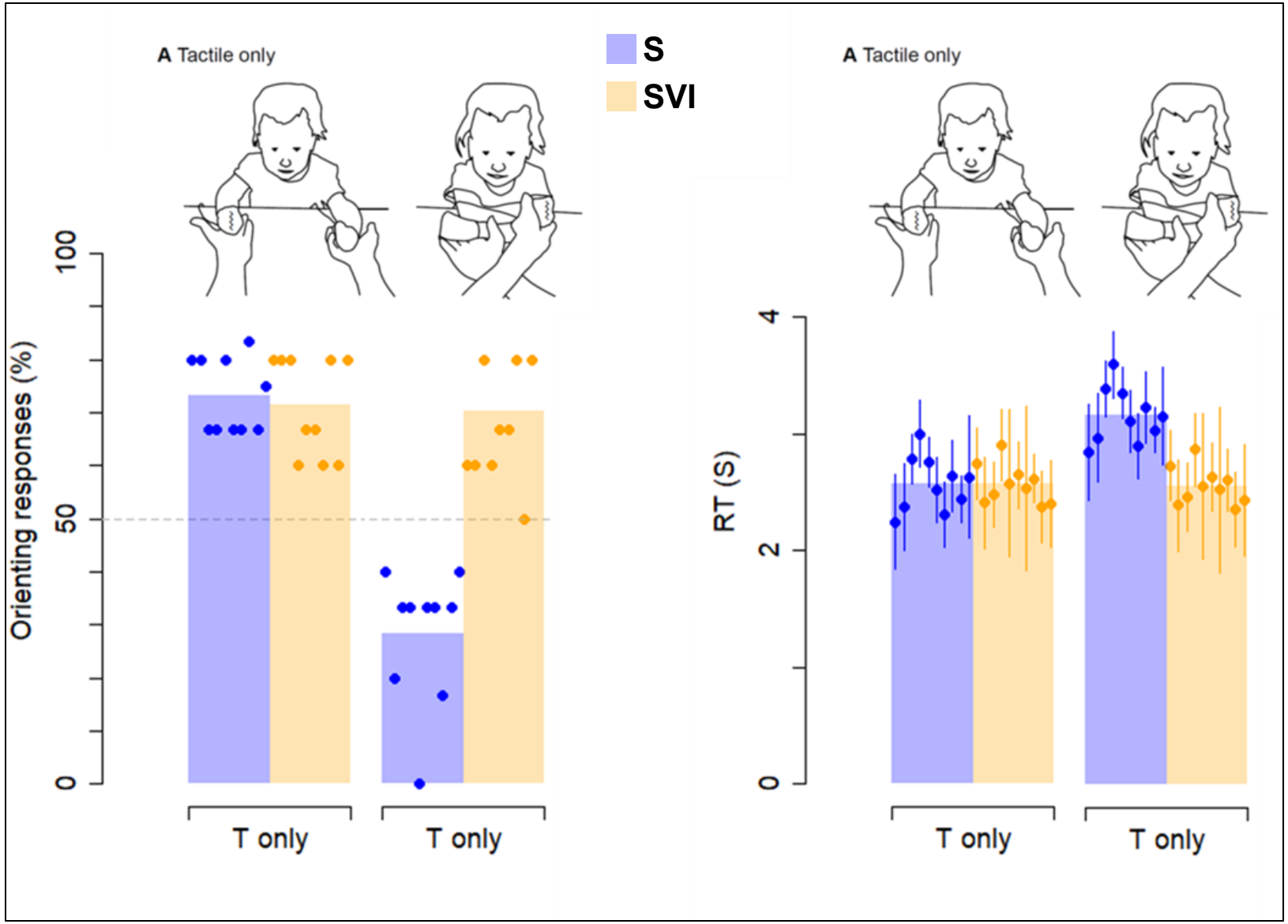
D Audiotactile incongruent



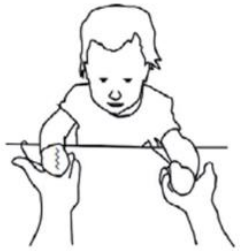
Uncrossed-hands

Crossed-hands

Vision plays an essential role from the very first years of life in the ability to remap somatosensory information into external space.



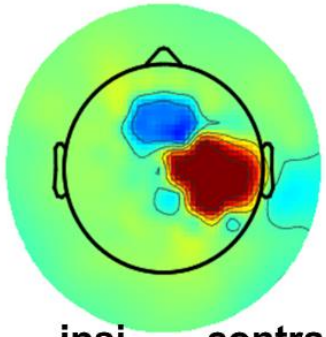
Gori et al., 2021, Current Biology

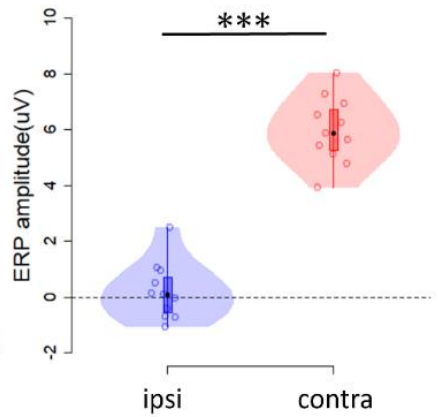


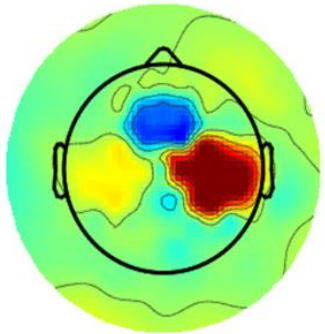
S ipsi
S contra
SVI ipsi
SVI contra

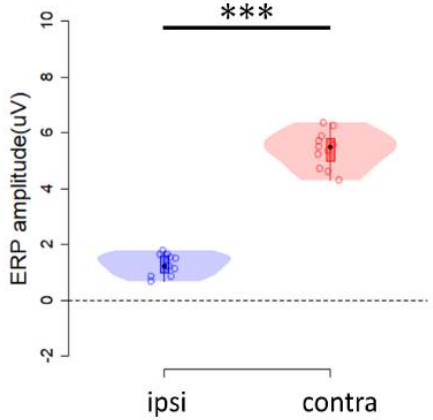
Tactile Only: mean ERP amplitude [45-65]ms

Sighted
N = 12

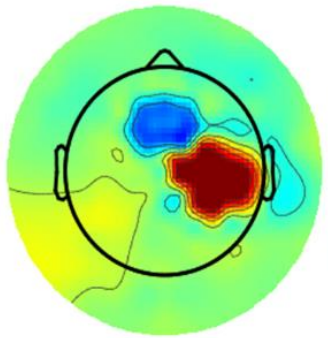


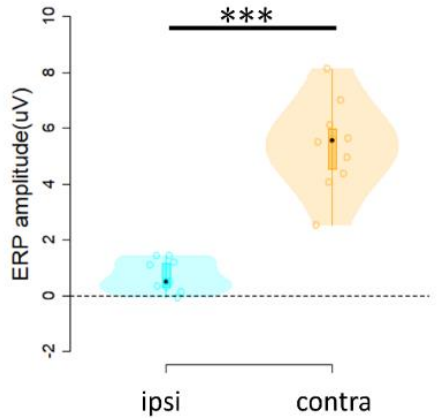


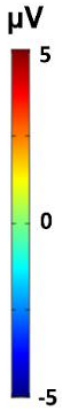


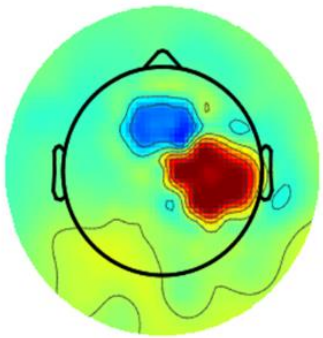


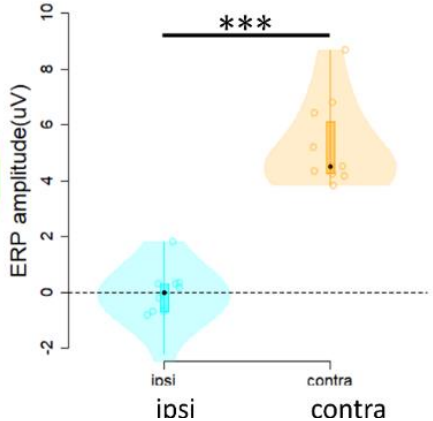
SVI
N = 12

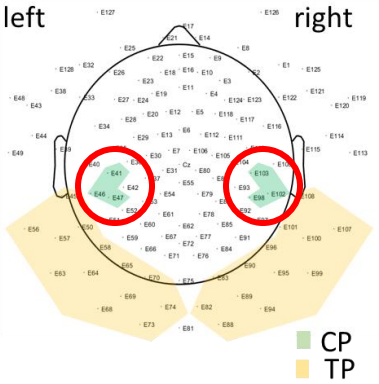








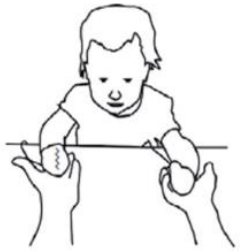




LMM: ERP mean~ Group(SVI/S)*Posture(Uncrossed/Crossed)* Laterality(Ipsilateral/Contralateral)+(1|participant).

Gori†, Vitali†, et al., 2025 Iscience

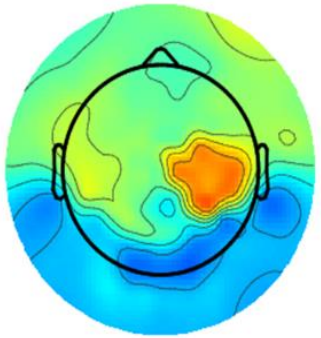
Vision drives the development of the specific neural mechanisms related to spatial remapping.

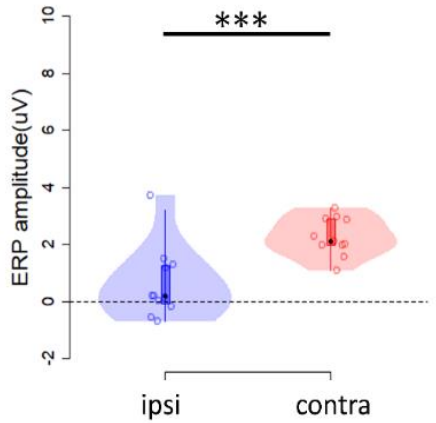


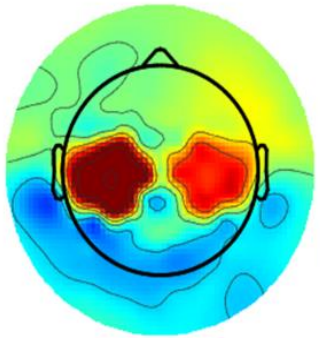
S ipsi
S contra
SVI ipsi
SVI contra

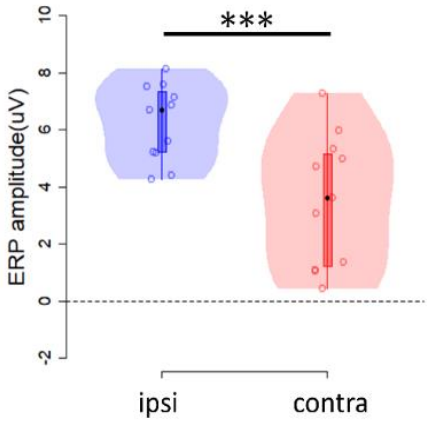
Tactile Only: mean ERP amplitude [105-120]ms

Sighted
N = 12









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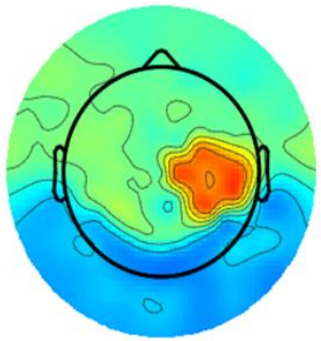
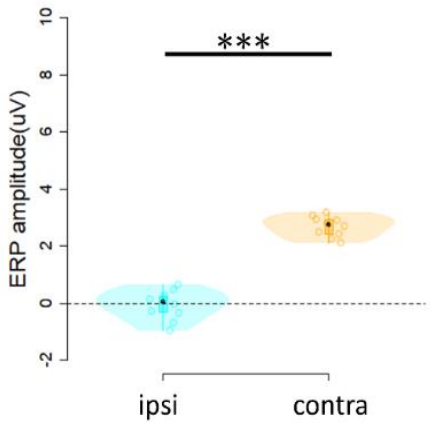
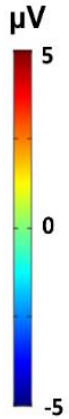
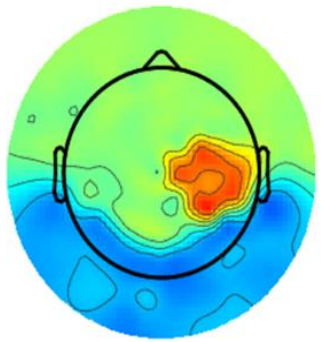
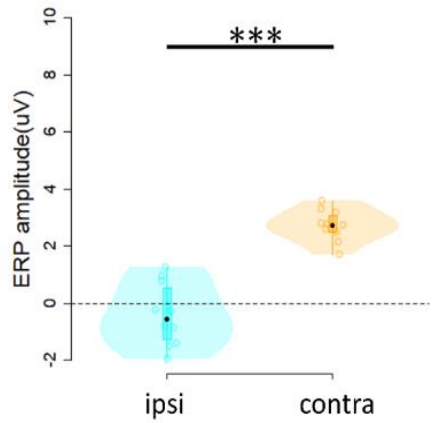
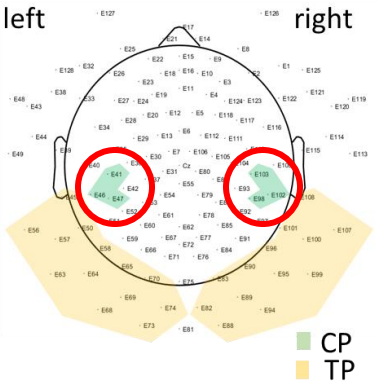








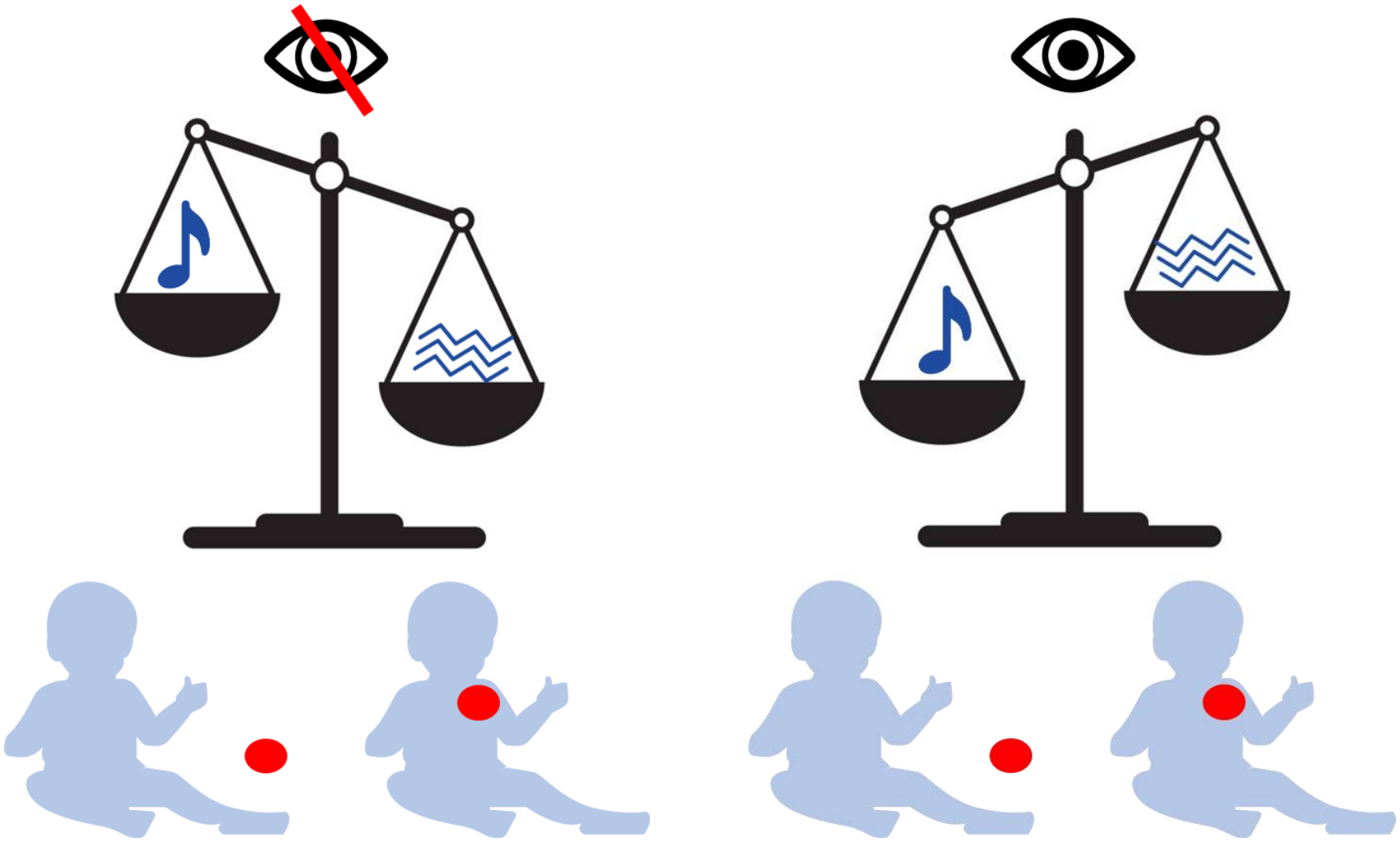




LMM: ERP mean~ Group(SVI/S)*Posture(Uncrossed/Crossed)* Laterality(Ipsilateral/Contralateral)+(1|participant).

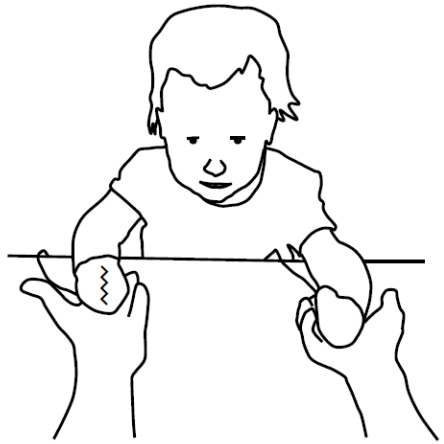
Gori†, Vitali†, et al., 2025 Iscience

Hp: Are the senses they mainly refer to different?

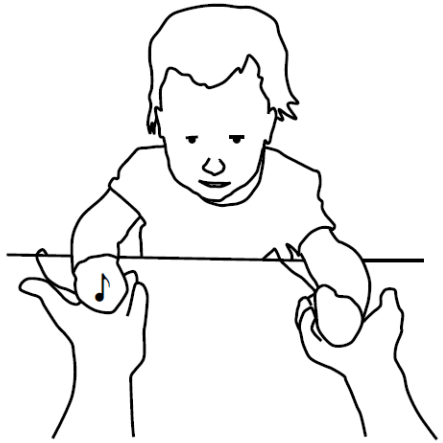


Gori et al., 2021, Current Biology

A Tactile only

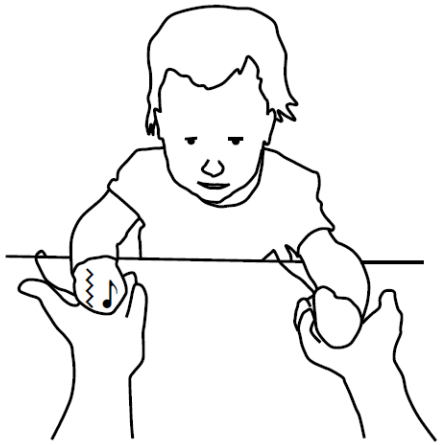


B Auditory only



♪ = Auditory stimulus
≀ = Tactile stimulus

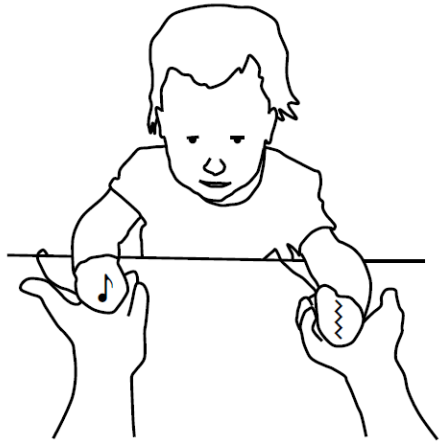
C Audiotactile congruent



Uncrossed-hands

Crossed-hands

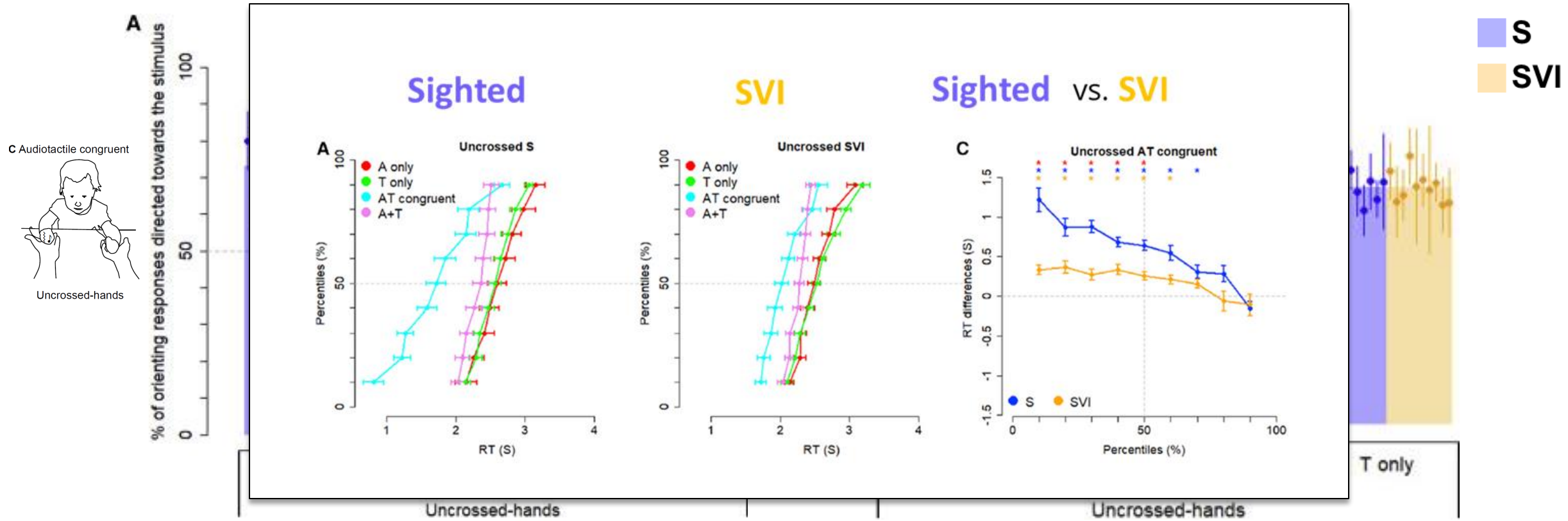
D Audiotactile incongruent



Uncrossed-hands

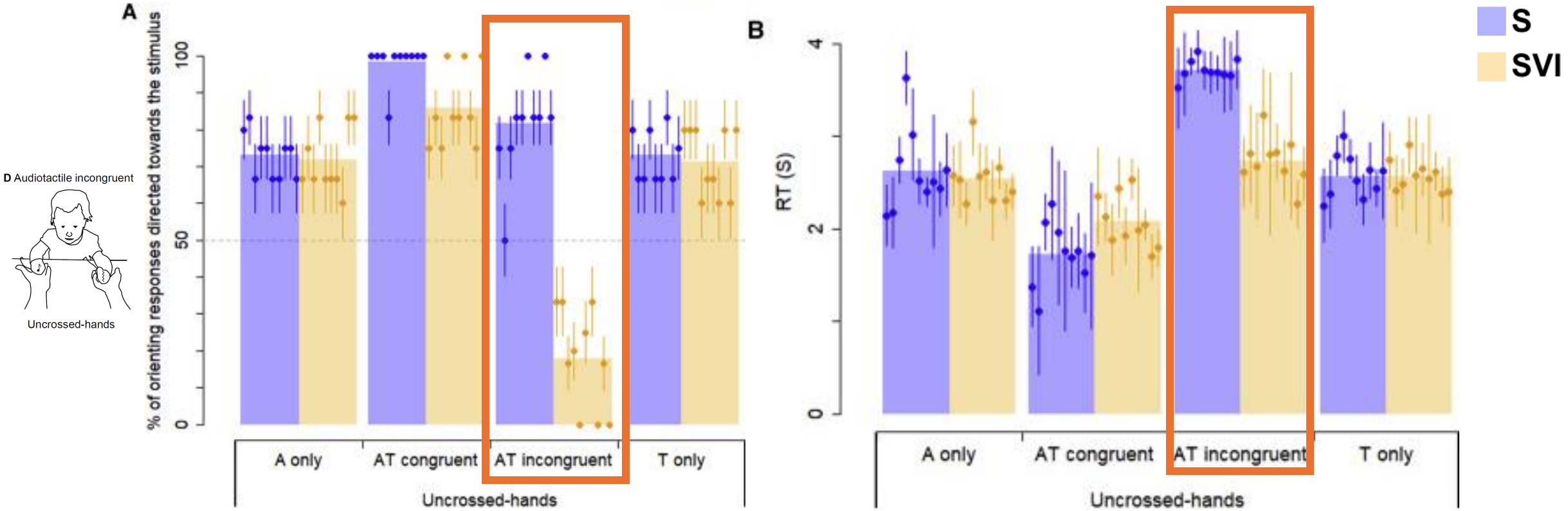
Crossed-hands

Stronger integration in sighted than in SVI infants



Gori et al., 2021, Current Biology

SVI infants tend to follow tactile stimuli, while S children respond more to sounds



Gori et al., 2021, Current Biology

Unpublished results

MSI localization: neural mechanisms involved

Congruent

- **Earlier processing** (105-120 ms)
- **S** stronger activation in auditory areas,
- **SVI** stronger activation in tactile areas

- **Later processing** (180-220 ms)
- **S** stronger activation in Fronto-Central
- **SVI** in Centro-Parietal area

Incongruent

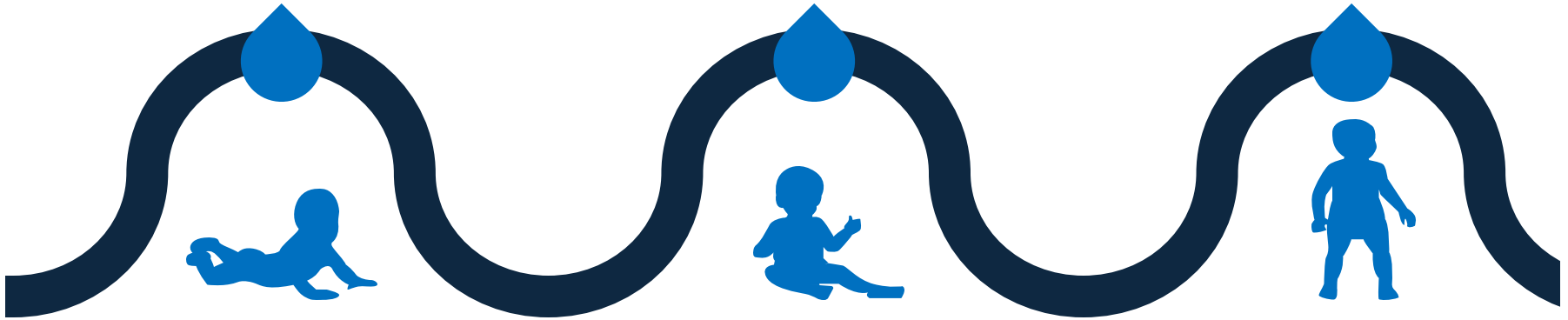
- **Earlier processing** (45-65/105-120 ms)
- **S** stronger activation in auditory and tactile areas with opposite behaviors,
- **SVI** stronger activation in tactile areas

- **Later processing** (180-220 ms)
- **S** behaviour modulates Fronto-Central activation
- **SVI** no significant activation is modulated by behaviors

Calafatello et al., in preparation

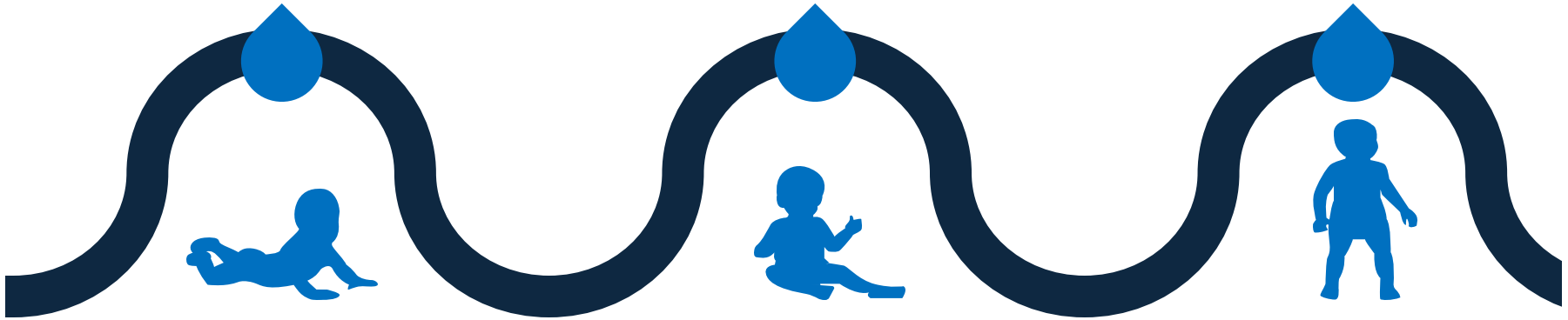
Brain and Multisensory Development

	• = alpha activity • ↓Sleep spindle activity	• ↓ Alpha activity • ↓ Sleep spindle activity • Associated with motor disfunction	• ↓ Alpha activity • Associated with motor disfunction
	• ↓ Cross-hand effect • ↑ reliance on tactile information and ↓ MSI		
	• Absence of the two-stage hierarchical mechanism of tactile spatial processing • ↑ tactile areas and MSI posteriorization		

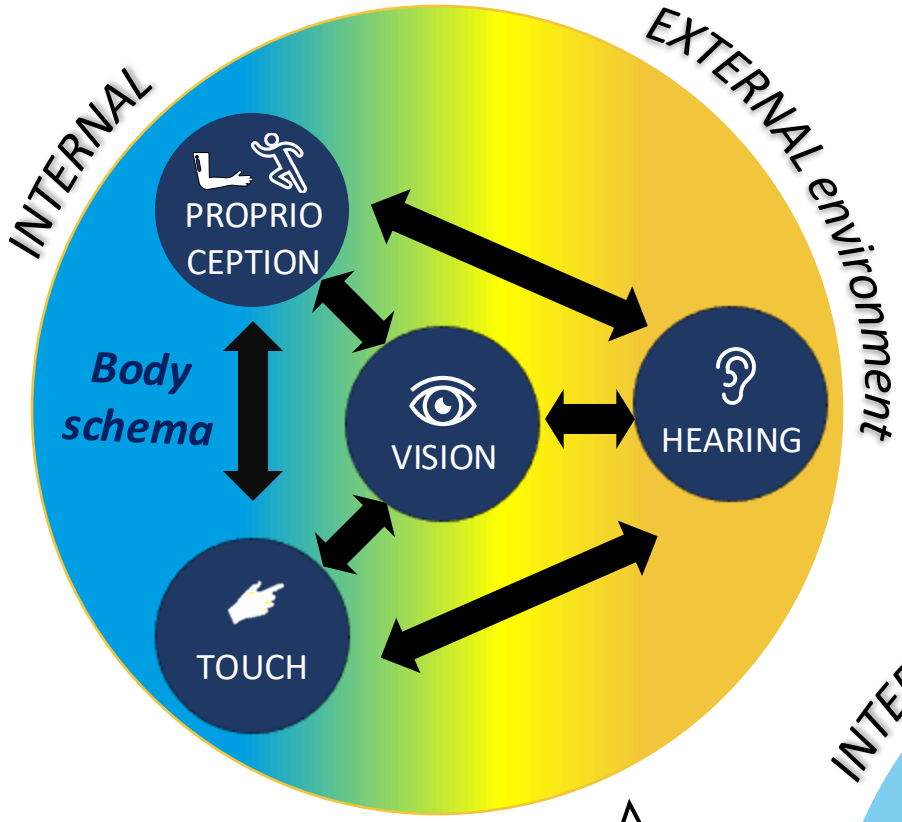


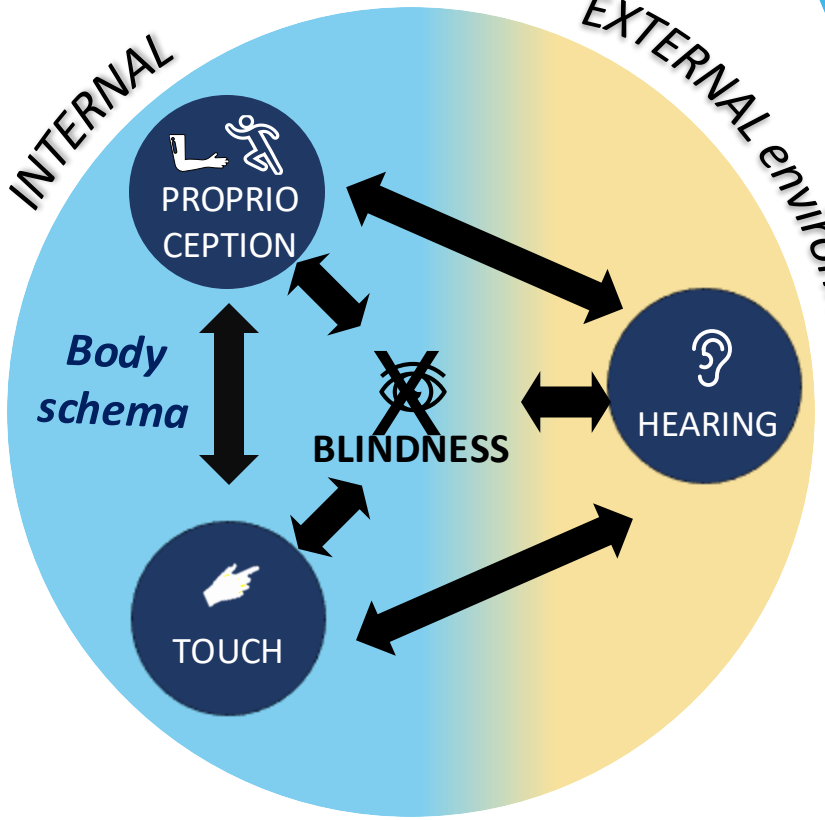
Brain and Multisensory Development

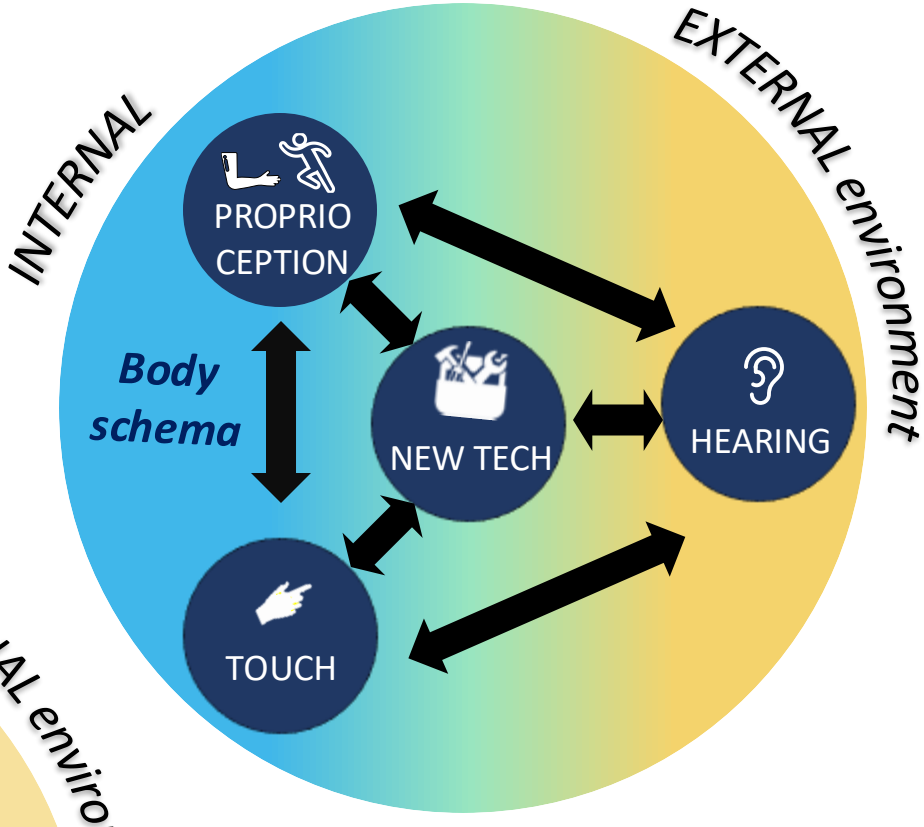
	• = alpha activity • ↓Sleep spindle activity	• ↓ Alpha activity • ↓ Sleep spindle activity • Associated with motor disfunction	• ↓ Alpha activity • Associated with motor disfunction
	• ↓ Cross-hand effect • ↑ reliance on tactile information and ↓ MSI		↓ AT ventriloquist *(Tonelli et al., 2026)* ↓ AT TBW and ↓ influence of body position (*Amadeo et al., 2025)* ↓ AT Rubber Hand Illusion *(Tammurello et al., 2026)*
	• Absence of the two-stage hierarchical mechanism of tactile spatial processing • ↑ tactile areas and MSI posteriorization		



These results highlight the importance of sensory interaction in scaffolding multisensory integration and body representation in infancy and during development.







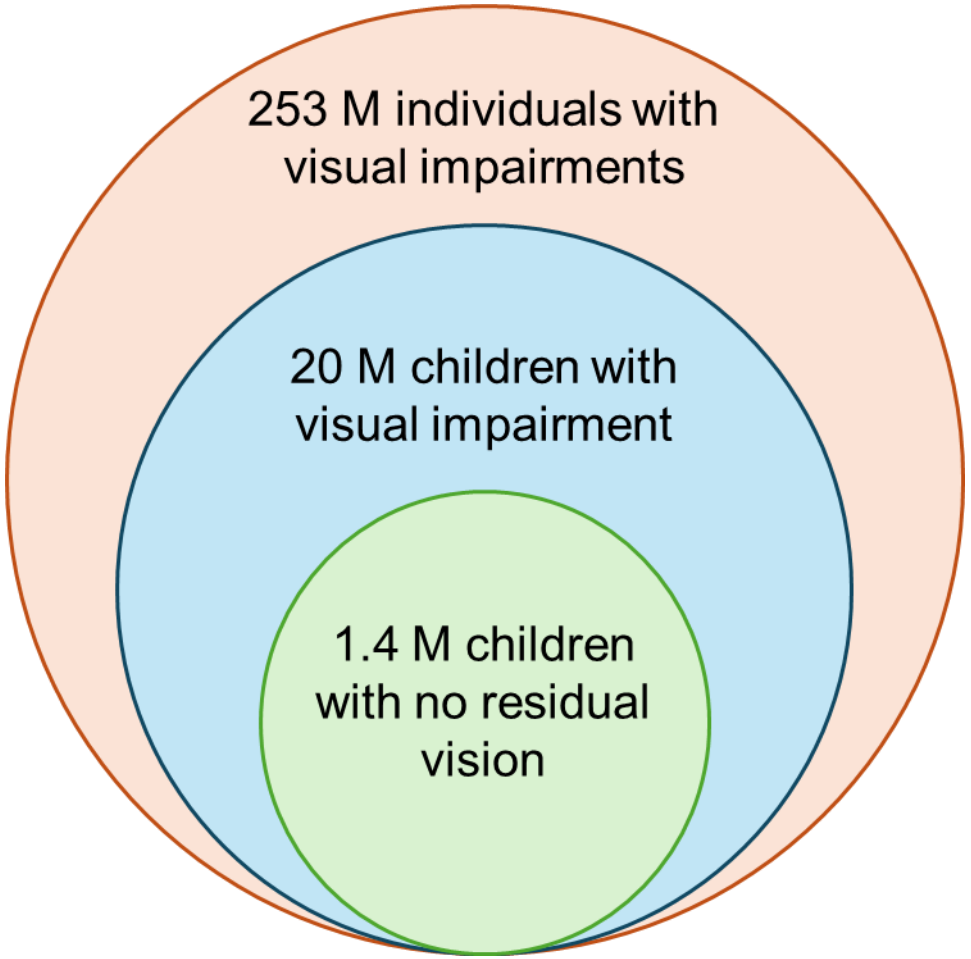
erc StG 2021

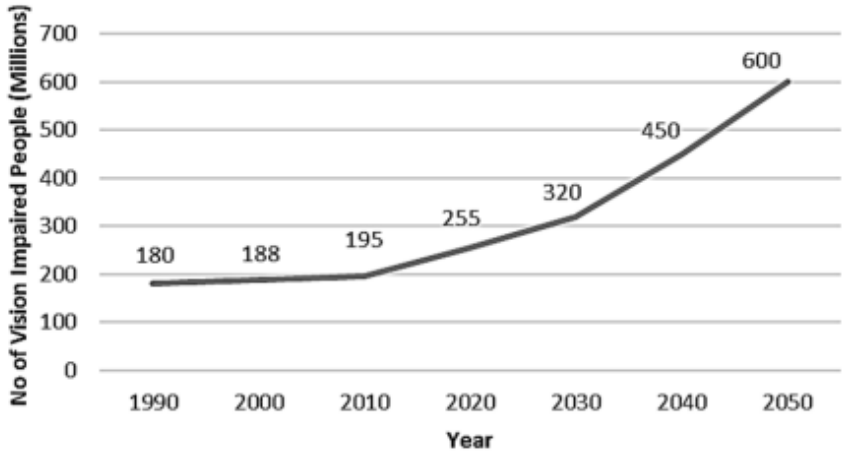
iReach

MySpace

erc PoC 2023

World Health Organization





From: Madake, J., Bhatlawande, S., Solanke, A., & Shilaskar, S. (2023). A qualitative and quantitative analysis of research in mobility technologies for visually impaired people. IEEE Access, 11, 82496-82520.

ABBI

***A**udio **B**racelet for **B**lind **I**nteraction* designed to facilitate body perception and movement in children with visual impairment

After **3 months** of rehabilitation with ABBI, visually impaired children (5-15 y.o.) show improvements in spatial localization and movement reproduction tasks.

(Evaluation of the Audio Bracelet for Blind Interaction for improving mobility and spatial cognition in early blind children – A pilot study, Finocchietti et al., IEEE EMBC 2015)

Sound and **Bu**zz

A smartphone and smartwatch application that contains a set of active and social "plug-and-play" audio-motor games based on the augmentation of body movements via sounds and vibrations. This app will allow tracking of the child's performance over time.

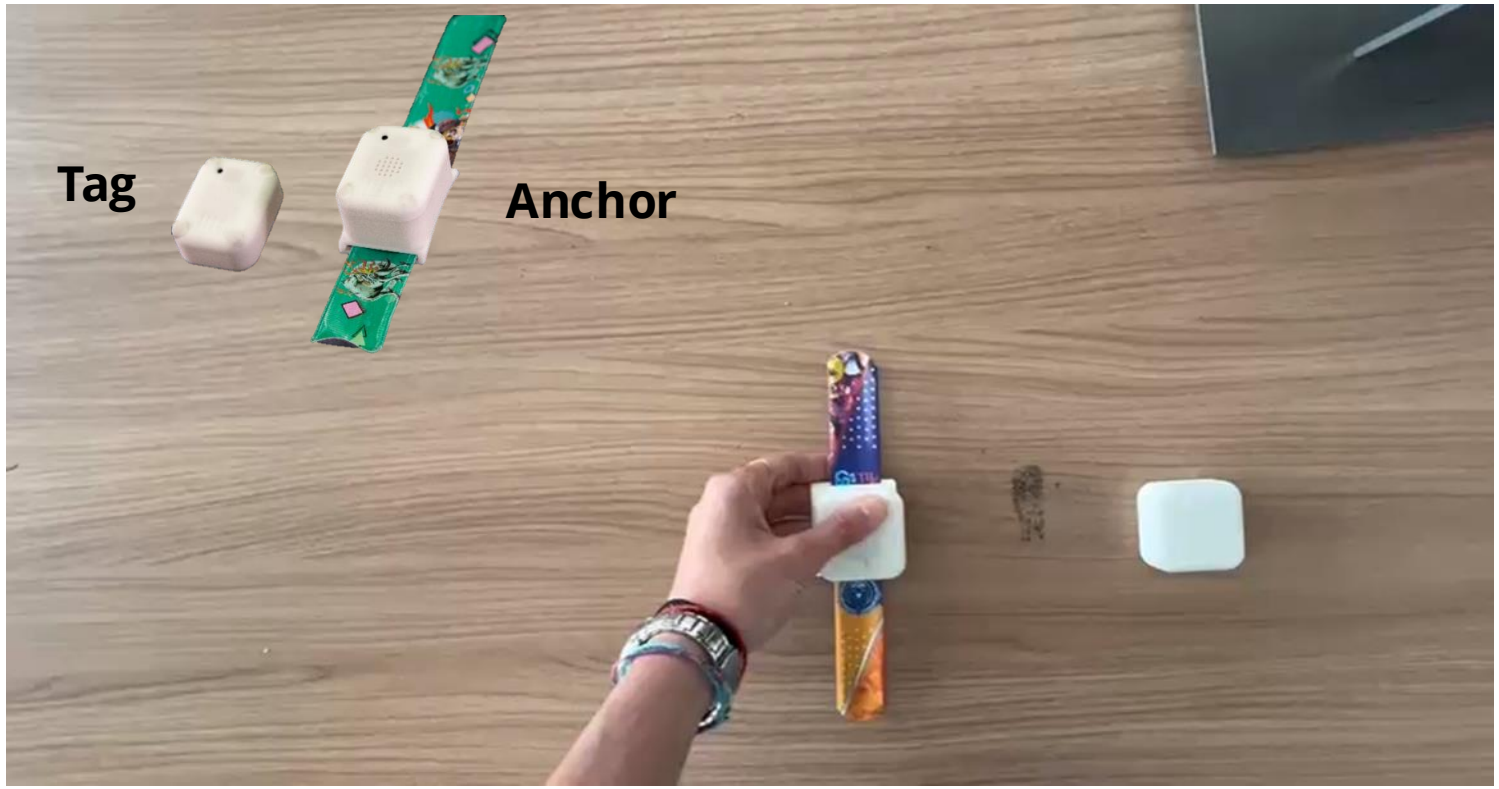
Dr. Davide Esposito

Dr. Walter Setti

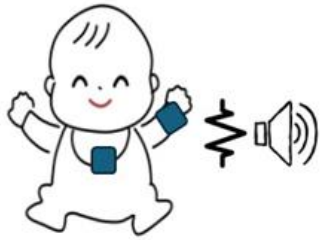
Dr. Nicolò Balzarotti

https://sobu.app/

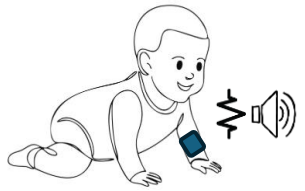
It is a multisensory device to promote body and spatial awareness in visually impaired infants and children



Body perception



Space perception



Petri, S., et al. 2025, IEEE MeMea; Gori M., et al., 2025, Frontiers in Psychology

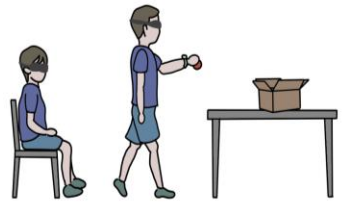
Experimental procedure

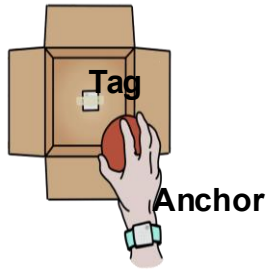
6 blindfolded children

iReach 2 (1 F, mean age 6 ± SD 1.4 y.o.)

ABBI 2 (2 M, mean age 5 ± SD 0 y.o.)

2 (1 F, mean age 5 ± SD 2.8 y.o.)





Task

3 types of objects: markers, cubes, balls

3 box positions: left, center, right

18 trials in total

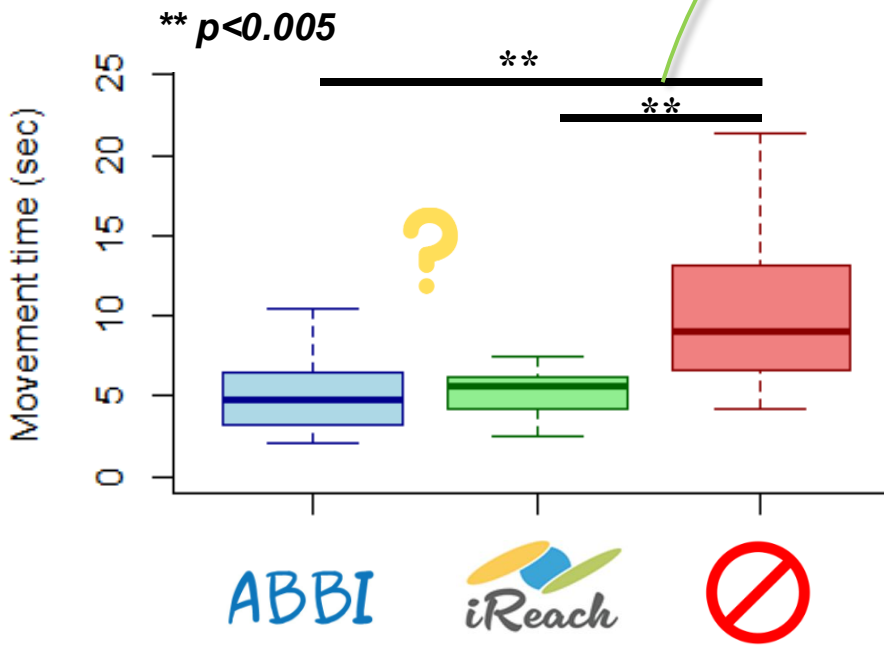
Hypotheses

i) Children using ***ABBI*** and ***iReach*** complete the task faster than those ***without devices***

ii) Children using ***iReach*** complete the task faster than those using ***ABBI***

Preliminary results

Only the trials where the object entered the box were considered



Children using ***ABBI*** and ***iReach*** complete the task faster than those ***without devices***

Children using ***iReach*** complete the task faster than those using ***ABBI***

Multisensory devices can help blindfolded children to be faster during a playful task

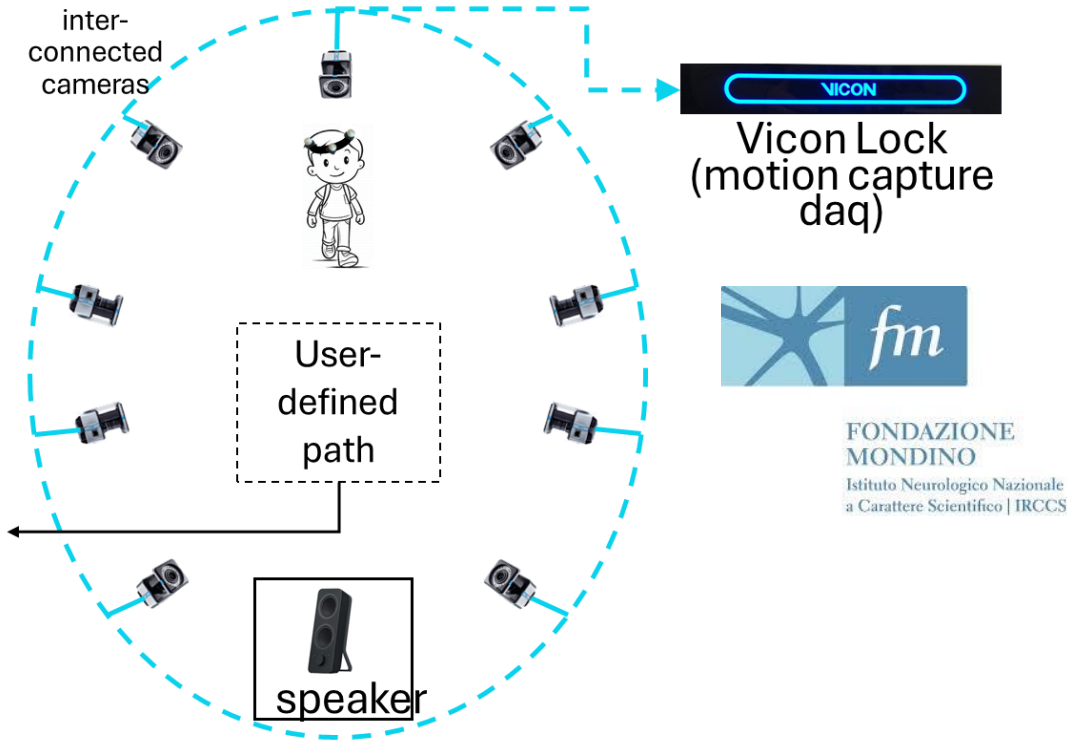
iReach lets children complete the task as fast as with ABBI

Longer training with iReach would support the child to fully understand sensory feedback spatial modulation

SONIA

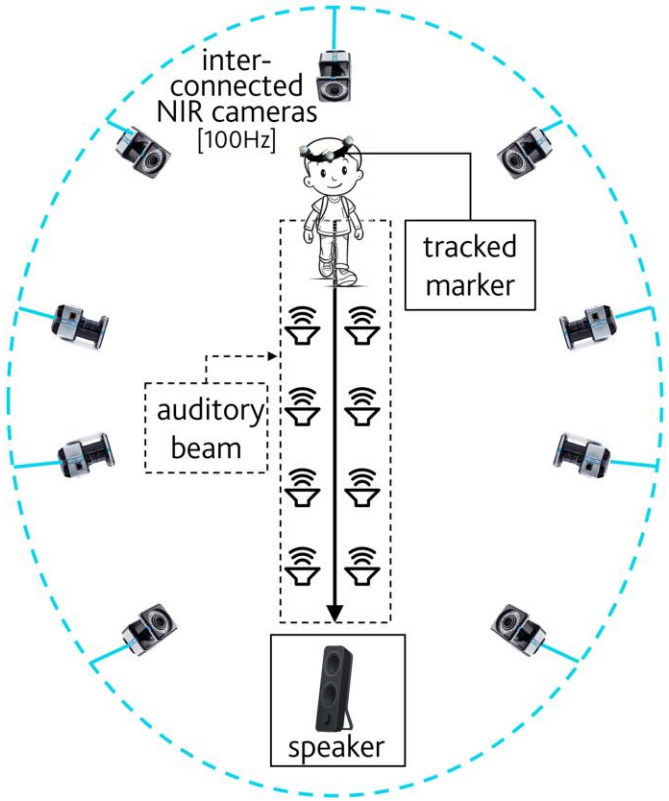
Sonification **o**f **N**avigation and **I**nteractive **A**ctivities

A framework designed to guide blind people along user-created paths. It relies on the principle of **sonification:** the conversion of motion-tracking data into auditory stimuli.



FONDAZIONE MONDINO
Istituto Neurologico Nazionale a Carattere Scientifico | IRCCS

Montagnani , Memeo, Guarischi, Catalano, Crepaldi, Signorini, Gori (2025): SONIA: a Real Time Automated Framework for Sonification and Interactive Activities in Visually Impaired Children. IEEE EMBC, Copenhagen, Denmark



Bambini bendati
8.7 ± 1.3 anni

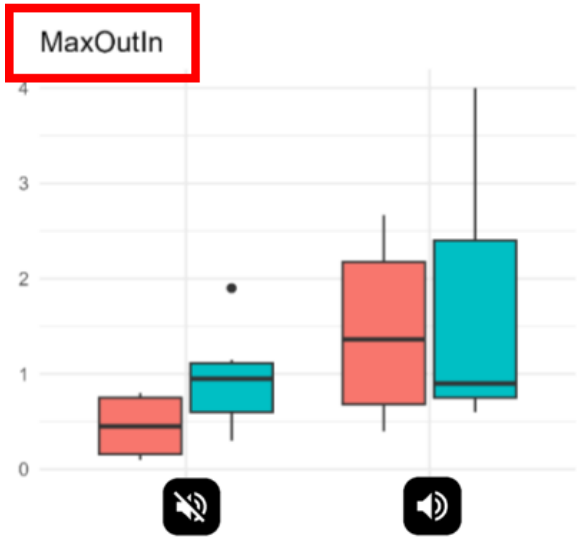
2 4

Adulti bendati
29 ± 1.7 anni

6

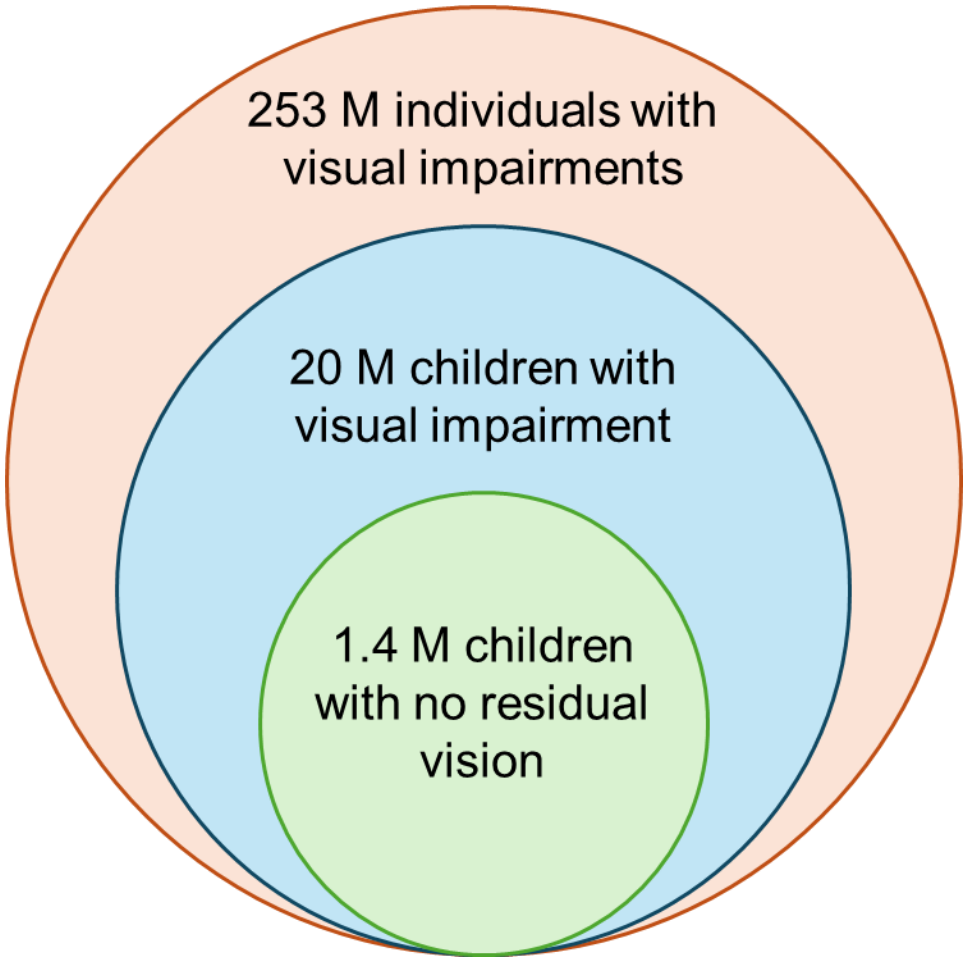
Table 1. Summary of p-values calculated with the ezPerm function to test effects in Groups (children vs adults), Condition (ON vs OFF) and their interactions.

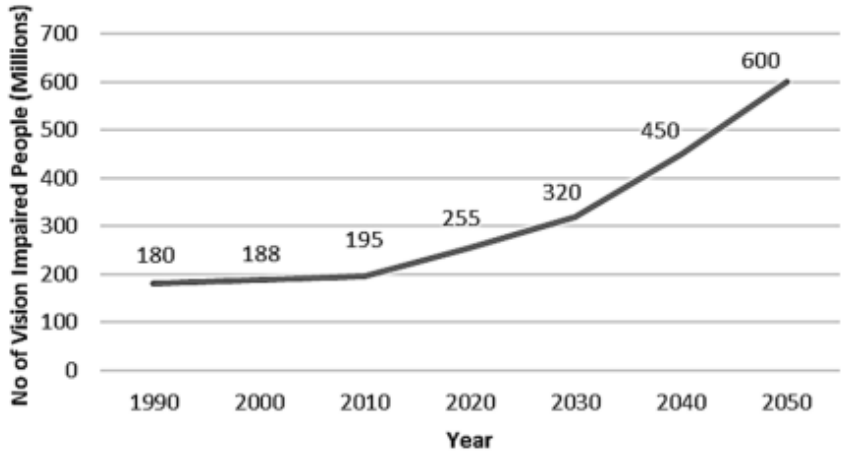
Variables	Group effect (*p*)	Condition effect (*p*)	Interactions (*p*)
MeanDurationIn	0.64	0.29	0.53
MeanDurationOut	0.74	0.22	0.57
MaxOutIn	0.44	0.01**	0.61
MeanMaxCoordOut$_x$	0.50	0.34	0.96
MaxTime	0.15	0.12	0.33
MeanVelocity	0.20	0.005***	0.16



Statistics
ezPerm (data ~
dv=.(dependent variable),
random=.(participants),
within=.(,),
between=.(adults, children)

World Health Organization





From: Madake, J., Bhatlawande, S., Solanke, A., & Shilaskar, S. (2023). A qualitative and quantitative analysis of research in mobility technologies for visually impaired people. IEEE Access, 11, 82496-82520.

Our technology aims to support therapists in the rehabilitation of sensory-motor functions, spatial perception, and body awareness.

SOCIETY for NEUROSCIENCE

ISTITUTO ITALIANO DI TECNOLOGIA
UNIT FOR VISUALLY IMPAIRED PEOPLE

PI

Team support

Campus

De Luca

MELD

PhD Student — 1° year

PhD Student — 1° year

PhD Student — 3° year

PhD Student — 3° year

EEG Expert

Motion Tracking

Research support

Design Lead, Postdoc

Ago 2024

Operational Lead, Postdoc

Jan 2025

Tech Lead, Technician

Jan 2025

Zanchi

Marie Skłodowska-Curie Actions Postdoctoral Fellowship

Tonelli

Schiatti

erc

Multisensory space and body representation development with and without vision

MySpace

Tammurello

Riberto

Setti

Vitali

Vitale

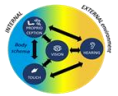
Campud

Coelho

Zanchi

Calafatello

Petri



Robotics and AI for socio-economic empowerment

RAISE

Esposito

Balzarotti

Shafique

Senacheribbe

Barbieri

Turri

Landolfi

Technology-mediated audio-motor spatial and social training for visually impaired children

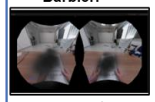
SONG

Setti

Balzarotti

Esposito

Barbieri



AlTered Reality

Esposito

VR and Audio

JOINT LAB

Montagnani

Balzarotti

Guarischi

Basta

Thanks for your attention!

Helene.vitali@iit.it

Italian network research hospitals

International network