Role of acoustic signal on equilibrium and space orientation

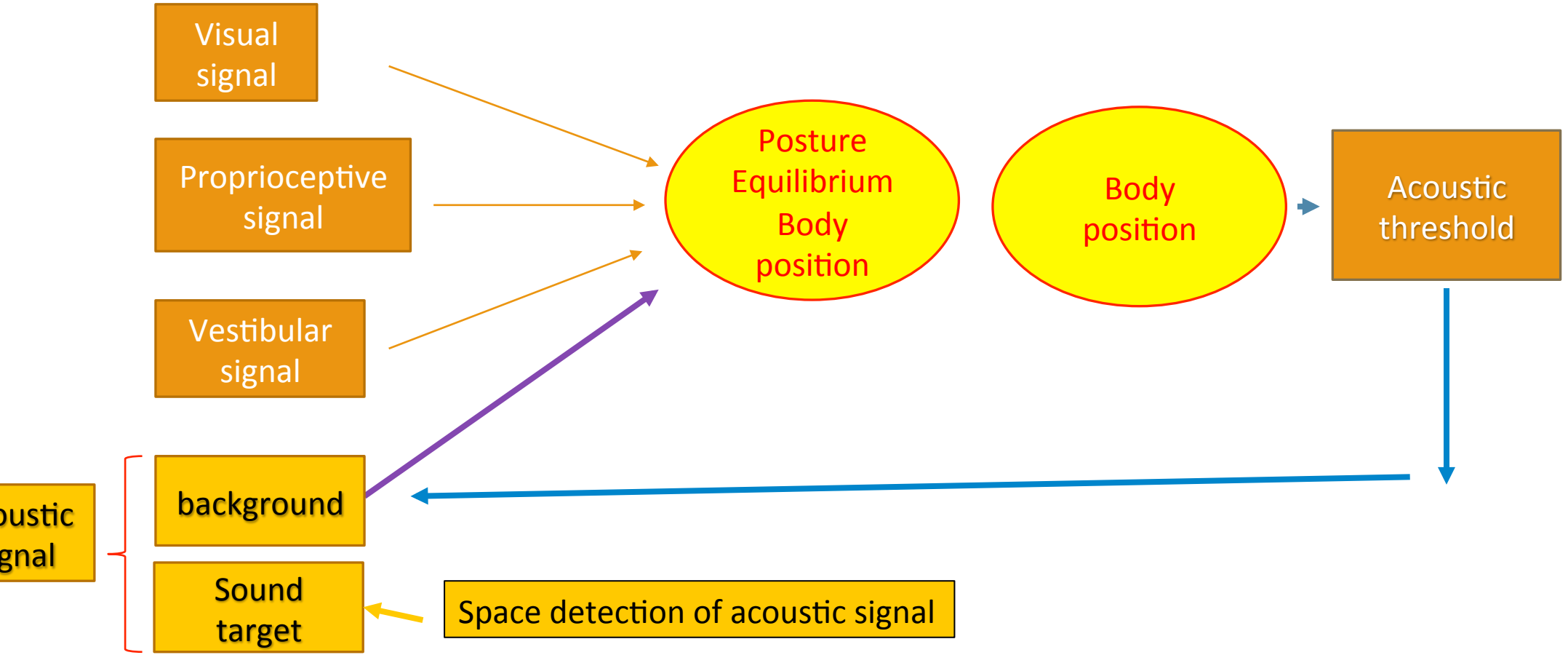
MASTER ROMA

2018 PETTOROSSI

Interazione sistema acustico e sistema vestibolare-equilib

I segnali acustici influenzano l'equilibrio?

La percezione acustica è influenzata dal sistema vestibolare e propriocettivo?

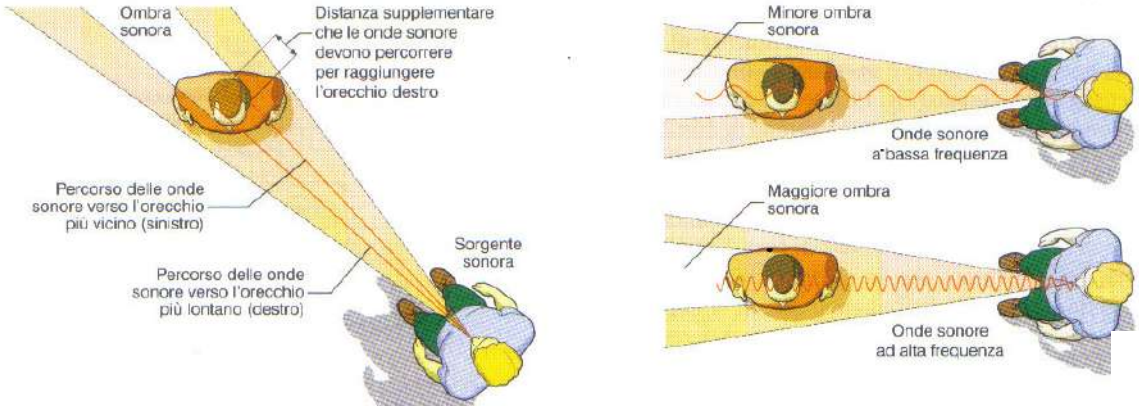


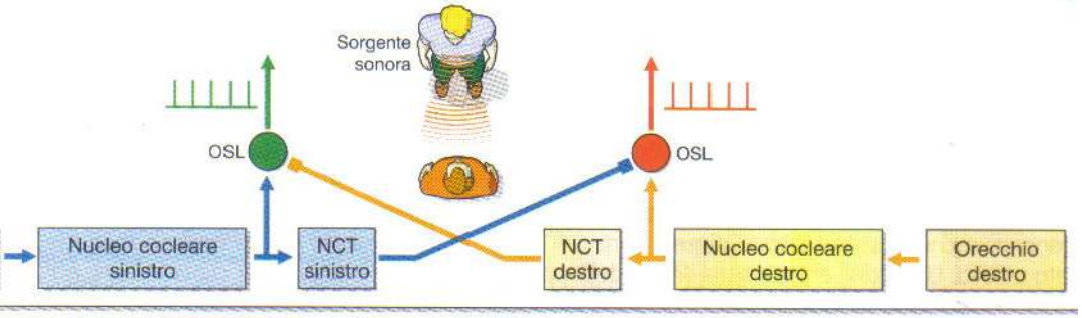
I segnali acustici sono importanti per la l'equilibrio (rischio di caduta) e per l'orientamento

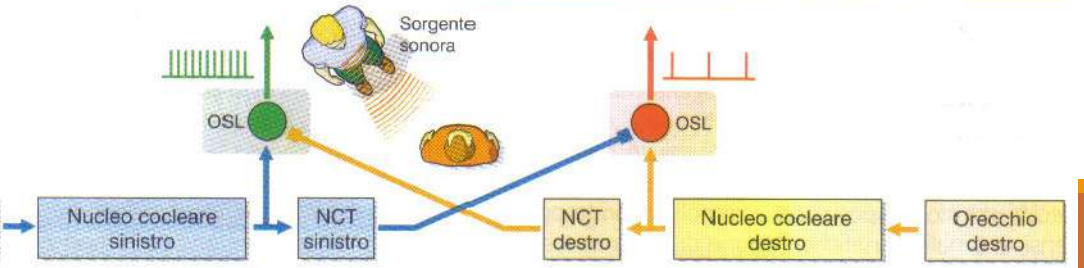
1. Il suoni di fondo (**background**)

2. I segnali acustici che **ancorano** punti nello spazio rispetto al soggetto definiti da

ocalizzazione spaziale dei suoni
ilevazione spaziale della diversa intensità,
se e ritardo,
he head-related transfer function.

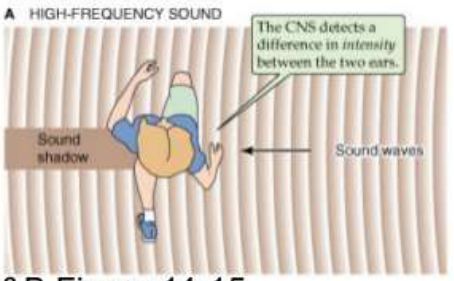


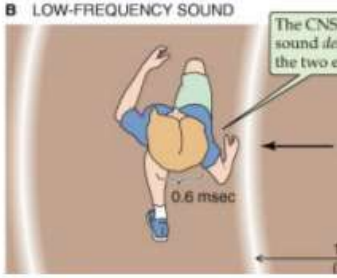




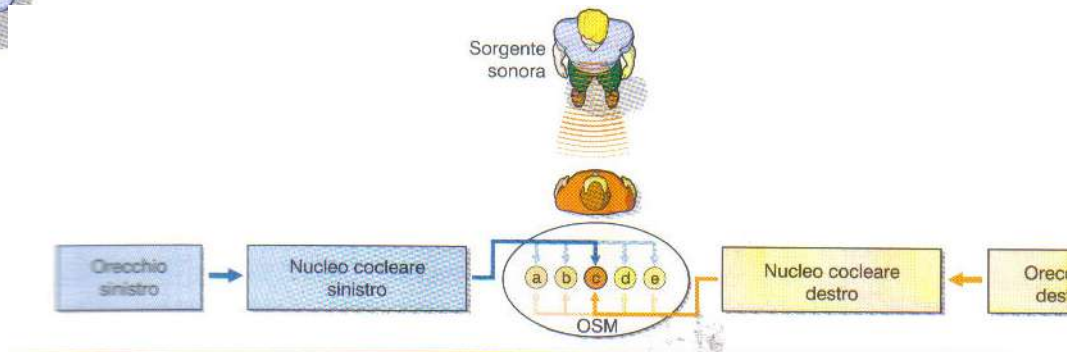
14

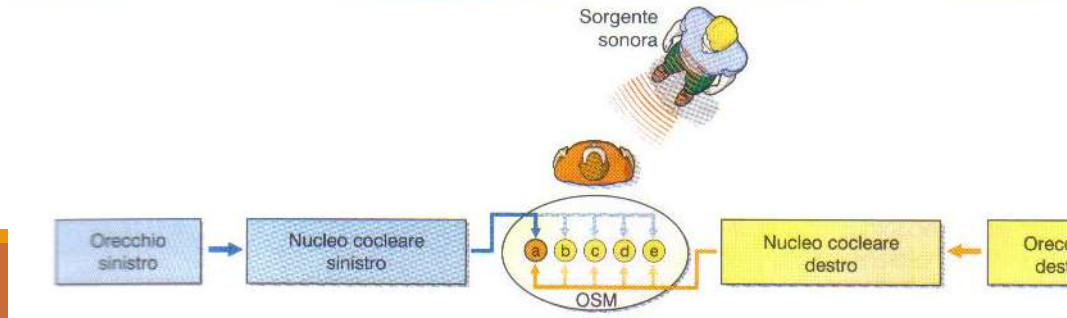
- two strategies to localize the *horizontal position* of sound sources depending on the frequency
  - frequencies above 3 kHz use **interaural intensity** differe
    - computed by neural circuitry in the lateral superior olive (L the medial nucleus of the trapezoid body (MNTB)
  - frequencies below 3 kHz use **interaural time** differences
    - computed by neural circuitry in the medial superior olive (





B&B Figure 14-15





Stato dell'arte suono-equilibrio

Il ruolo del Sistema acustico nell'equilibrio ha avuto minore interesse nel passato (due studi)

Juntunen, J. et al. **Postural body sway and exposure to high-energy impulse noise**. The Lancet(1987)

Era, P. & Heikkinen, E. **Postural sway during standing and unexpected disturbance of balance in random samples of men of different ages**. Journal of Gerontology (1985)

Recentemente è oggetto di indagini più approfondite

Gandemer, et al, **The influence of horizontally rotating sound on standing balance.** Experimental Brain Research(2014);

Ross, J. M. & Balasubramaniam, R. **Auditory white noise reduces postural fluctuations even in the absence of vision**. Experimental brain research (2015);

Rumalla, et al. **The effect of hearing aids on postural stability**. The Laryngoscope (2015);

Zhong, X. & Yost, W. A. **Relationship between postural stability and spatial hearing**. Journal of the American Academy of Audiology (2013);

Gago, M. F. et al. **Role of the visual and auditory systems in postural stability in alzheimers disease. Journal of Alzheimer's Disease** (2015);

Mangiore, R. J. **The effect of an external auditory stimulus on postural stability of participants with cochlear implants** (2012).

Prime osservazioni sulle ipoacusie e il rischio di cadute

Viljanen, A. et al. **Hearing as a predictor of falls and postural balance in older female twins**. The Journals of Gerontology (2009).
Lin, F. R. & Ferrucci, L. **Hearing loss and falls among older adults in the United States**. Archives of internal medicine (2012
Kilburn, K. H., et al. **Are hearing loss and balance dysfunction linked in construction iron workers?** British journal of indus medicine (1992).
Suarez, H. et al. **Balance sensory organization in children with profound hearing loss and cochlear implants.** Internationa journal of pediatric otorhinolaryngology (2007)

Il danno acustico può essere associato ad un deficit nel sistema vestibolare oppure l'effe

dell'ipoacusia può essere per sé «**disorientante»**

Rumalla et al. (2015) compared the postural sway of hearing-aid users, **Postural performance of subjects was significant better** in condition proving the benefits of having auditory input fully available

External sound stimulation has been shown to influence body sway particularly in the medial–lateral axis (Tana al., 2001; Priplata et al., 2002)

The influence of moving auditory stimuli on standing balance in healthy young adults and the elderly. (Devitern al., 2005; Alessandrini et al., 2006; Dozza et al., 2007)

Auditory biofeedback substitutes for loss of sensory information in maintaining stance. (Tanaka T, et al. Exp Brai Res. 2007).

Auditory cues for orientation and postural control in sighted and congenitally blind people. (Dozza M, et al. Exp Brain Res. 1998)

Tutti gli studi stabilometrici riportati tendono a mostrare che la ncanza dell'input acustico determina una riduzione del controllo posturale

statici

gaonkar et al:

izioni: postural sway of subjects in various auditory environment:

al room, soundproof room, wearing ear defenders, eyes closed vs eyes open.

open) subjects exhibited a greater sway in the soundproof room vs in a normal room, or ng ear defenders vs without ear defenders.

sound stimulation exhibited a decrease of sway in presence of sound stimuli.

her study (Easton et al.), subjects were set in a tandem Romberg stance (heel-to-toe position) two sound sources on both sides of their head, eyes open vs eyes closed. Authors reported a **ease of sway of 10% of subjects in presence of auditory cues vs 60% in presence of visual cues** tudy highlighted the slightness of sound effect when compared to vision. In a more recent stud nvolving subjects in tandem Romberg stance, authors showed a decrease of sway of 9% of cts exposed to **a pink noise sound source facing them** .

Studi dinamici Other studies focused on the role of **moving** sound forced the subject to take into consideration the regularity and rotation of the stimulation, which sound sources (Deviterne et al.) **The results showed a stabilization of the subjects only in this meaningful condition** providing a **auditory anchorage.**

)**Studi con cuffie che eliminano l'influenza spaziale : Through headphones**, in that case, sound does not provide spatial cues (Ross and Balasubramaniam) **exhibited a significant reduction of subjects body sway when exposed to auditory stimuli through headphones** due to the "**stochastic resonance**" **phenomenon**.

Stochastic resonance is a phenomenon that occurs when a sensory signal containing information is subthreshold, that is, too weak to be detected and integrated by central nervous system. In that case, adding noise (a signal which does not contain information) to the initial sensory input amplifies the whole signal which can pass over the threshold and then be integrated

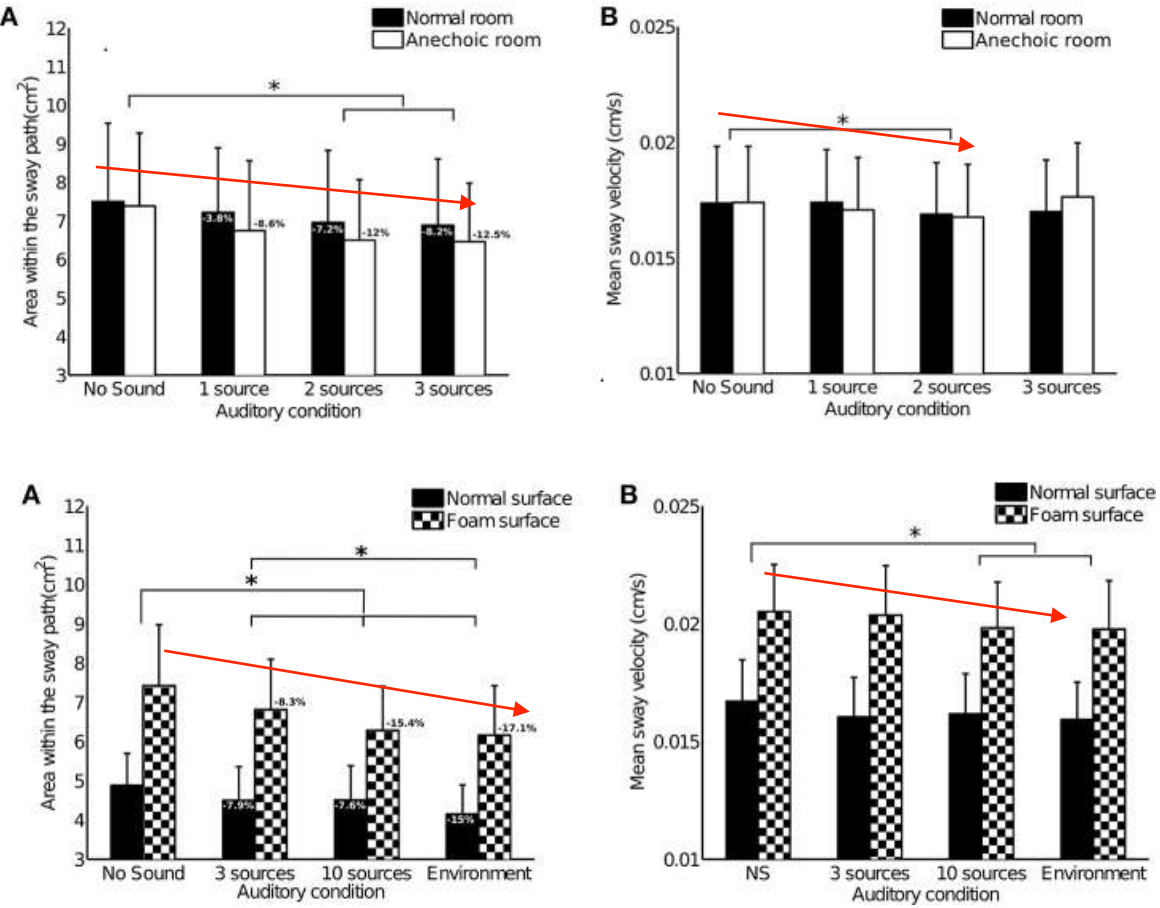
Evidenze di segno opposto

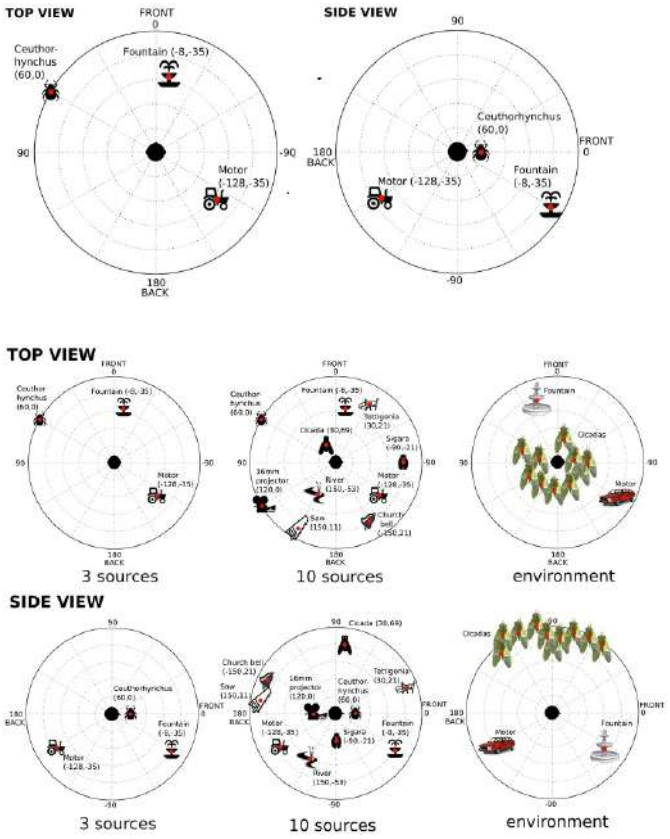
1) Lo **sway aumenta quando aumenta le frequenze dei suoni**. (ma non sufficientemente verificati con controlli).

2) Il background non informativo genera **distrazione ed instabilità**

Tanaka, T., et al. The influence of moving auditory stimuli on standing balance in healthy young adults and the elderly. Ergonomics (2001).
Park, et al. Effects of sound on postural stability during quiet standing. Journal of neuro-engineering and rehabilitation (2011).
Raper, S. & Soames, R. The influence of stationary auditory fields on postural sway behaviour in man. European journal of applied physiology and occupational physiology (1991).
Soames, R. & Raper, S. The influence of moving auditory fields on postural sway behaviour in man. European journal of applied physiology and occupational physiology (1992).

Review: Gandemer et al **Spatial Cues Provided by Sound Improve Postural Stabilization: Evidence of a Spatial Auditory Map?** Front Neurosci 2017





eview: **Gandemer et al Spatial Cues Provided by Sound Improve Postural Stabilization: Evidence of a patial Auditory Map?** Front Neurosci 2017

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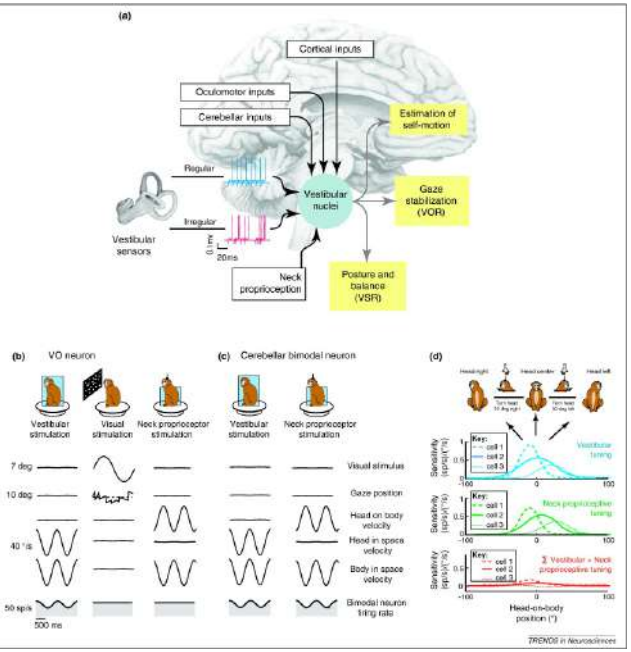
onclusione:

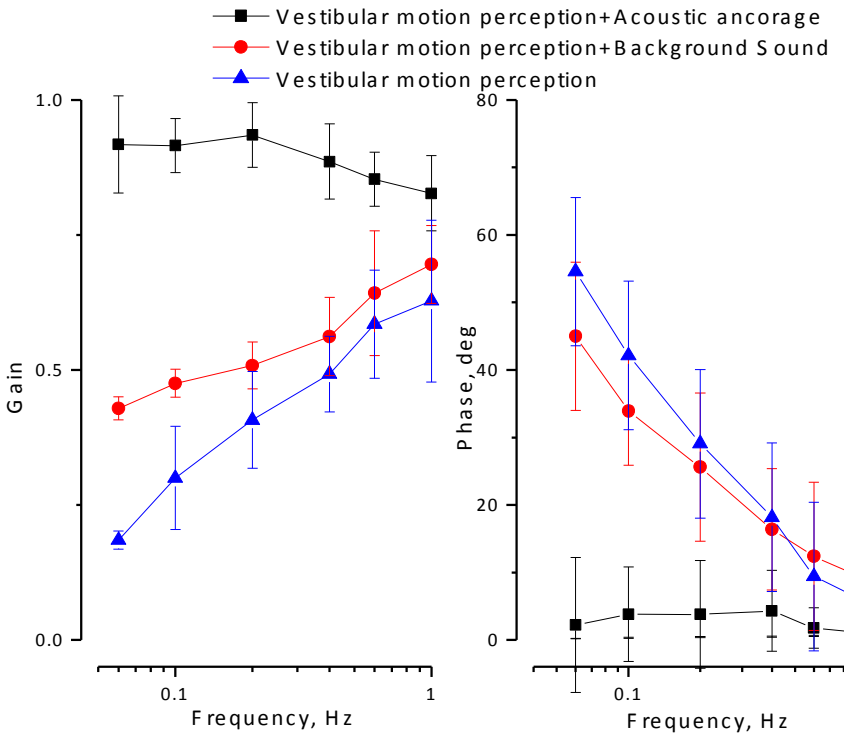
o studio su giovani, sani senza il supporto della visione, consente di ritenere che il uono costruisce centralmente la **«spatial hearing map»**: rappresentazione nentale dello spazio attorno e the landmark che aiutano a essere più stabili nello pazio.

e caratteristiche più importanti sono legate all'**attenzione**, la **rilevanza di ignificato**, la **ricchezza dei suoni**, e la loro **natura**. In posizione eretta le **alte requenza** migliorano il controllo postural, mentre lo spettro e l'intensità non embrano avere importanza. (Siedlecka et al, 2015)

Contributo dei segnali acustici alla percezione spaziale: dove è il mio corpo rispetto al suono?
Background ed Ancoraggio acustico

e hippocampus (Sharp et al. 1995), **the posterior parietal**
rtex and the **parieto-insular vestibular cortex** (Brandt &
eterich, 1999; Seemungal et al. 2009; Lopez & Blanke, 2011).
uronal study (Grassi et al. 1995; Pettorossi et al. 2011)
llen)**: different neurons for VOR ansd perception**

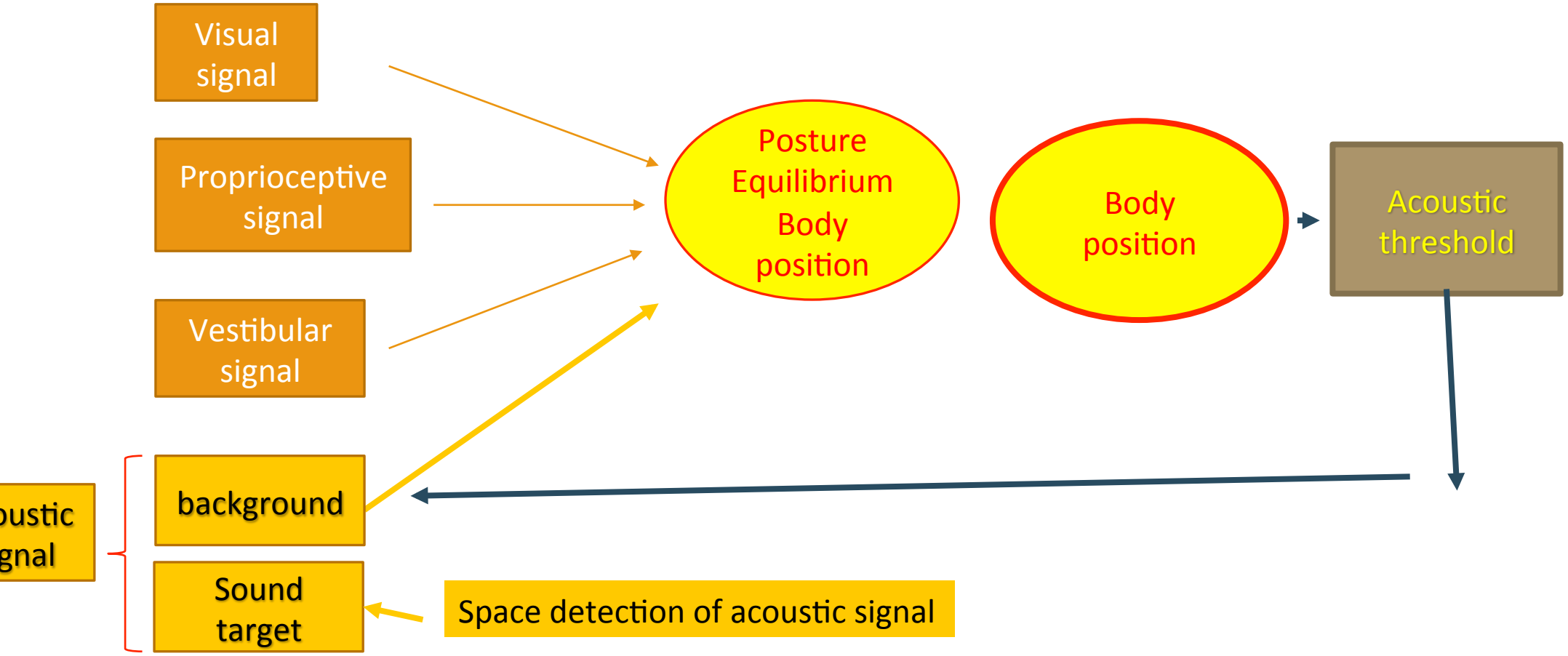




Self motion perception and acoustic target location (Pettorossi et al,2005)

Interazione sistema acustico ed equilibrio

La percezione acustica è influenzata dal sistema vestibolare e propriocettivo?



1. Sono in grado di sentire un suono mentre mi muovo?

2. Sono in grado di sentire un suono se la posizione del suono re-corpo è diversa ?

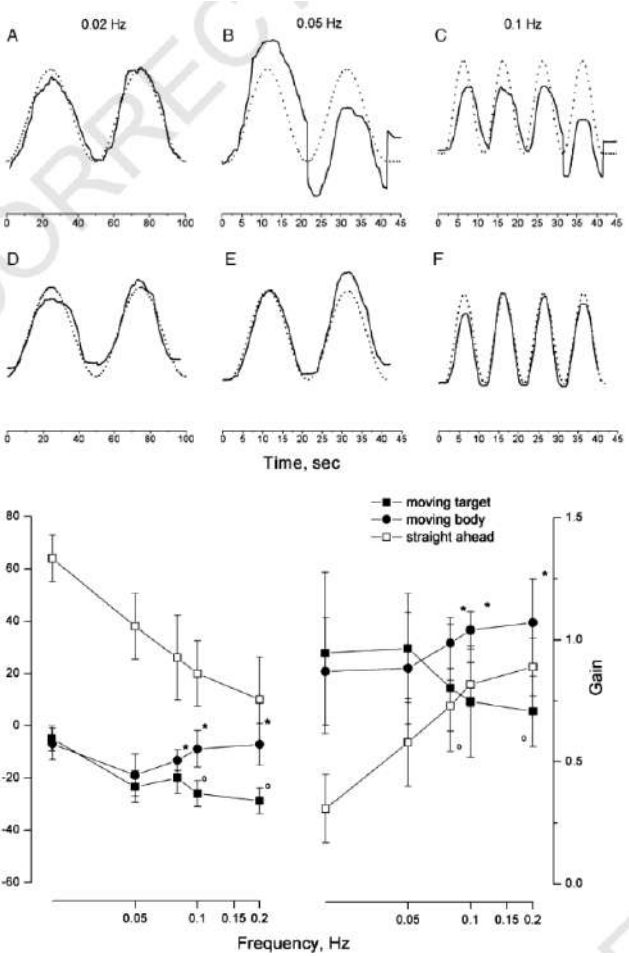
3. Quale è il riferimento del corpo più importante?

The ability to localize and pursuit sounds in space depends on craniocentric coordinate system, but it is also influenced by body-centric and absolute allo-centric coordinates and the ability to recognize conversation in difficult listening conditions (Hirsh, 1950), depends on the ability of spatial location for better separating different sounds .

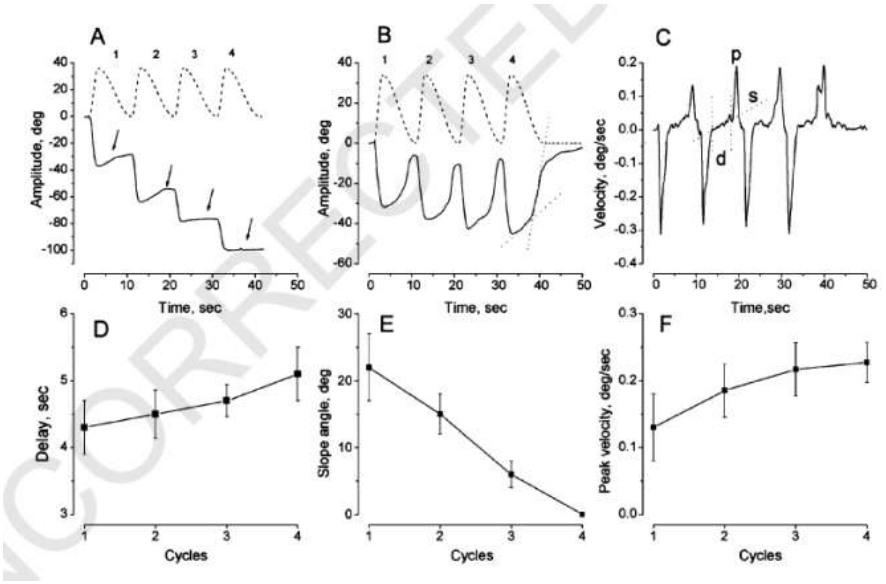
The precision of sound location in space. may depend on trunk position (REF), head tilt (REF) and the vestibular activation (REF (JNeurosci. 2012 Sep 26;32(39):13501-Schechtman E[1], Shrem T, Deouell LY.
Lewald (Pettorossi et al Wallach, 1940),, .
Since the (REF) i

Interazione acustico-vestibolare nella percezione del movimento

Self motion perception and acoustic target location (Pettorossi et al, Acta Oto-Laryng 2005).

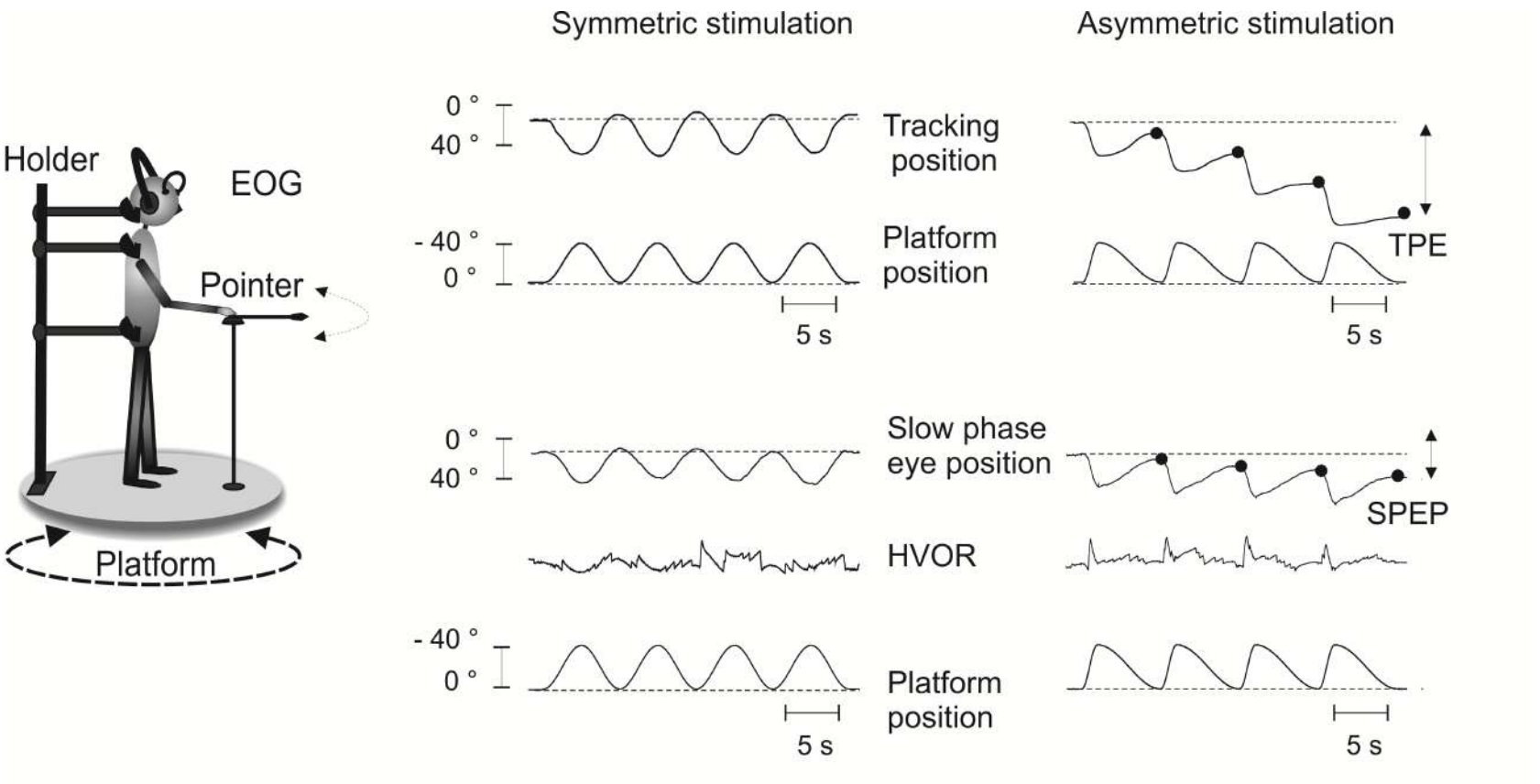


Contributo Acustico-
Vestibolare alla percezione
di movimento

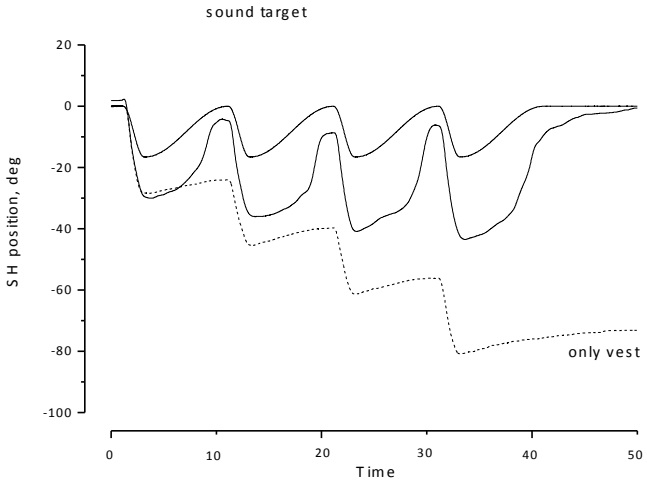


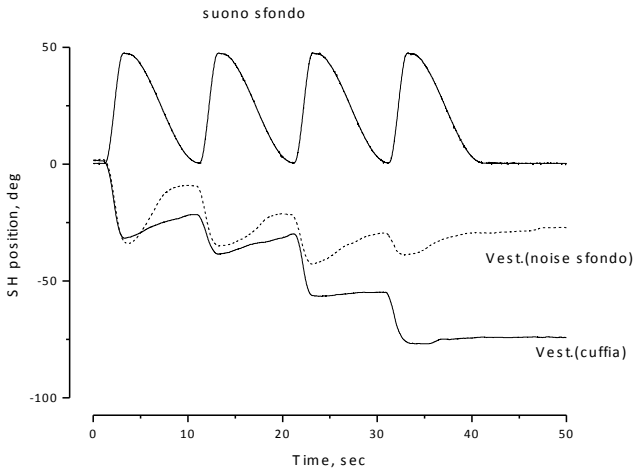
Correzione dell'errore
Vestibolare
da parte del sistema a

Stimoli asimmetrici



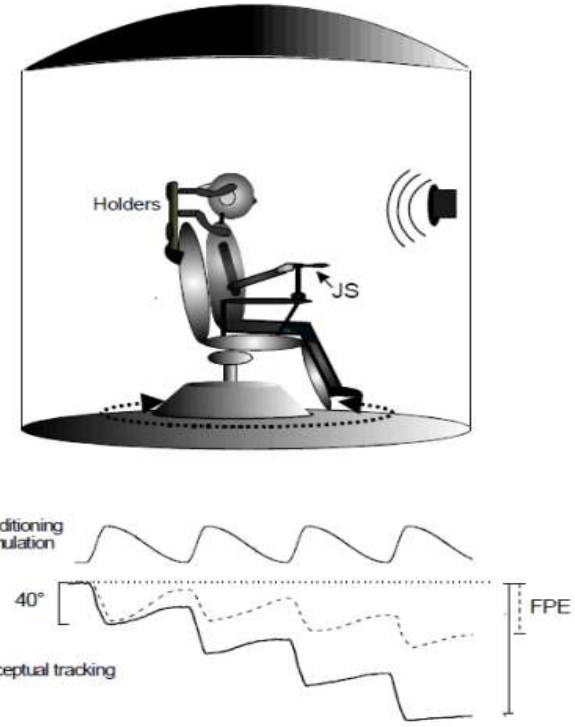
Self motion perception and acoustic target location (Pettorossi et al, J. Neurophysiol 2017).

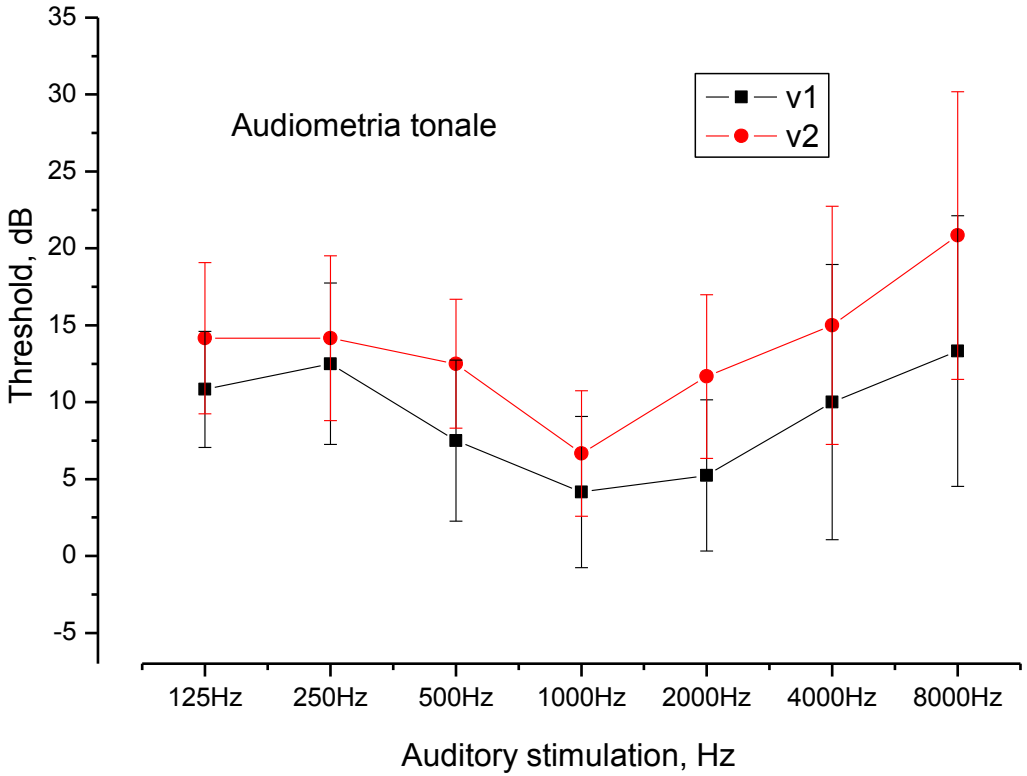




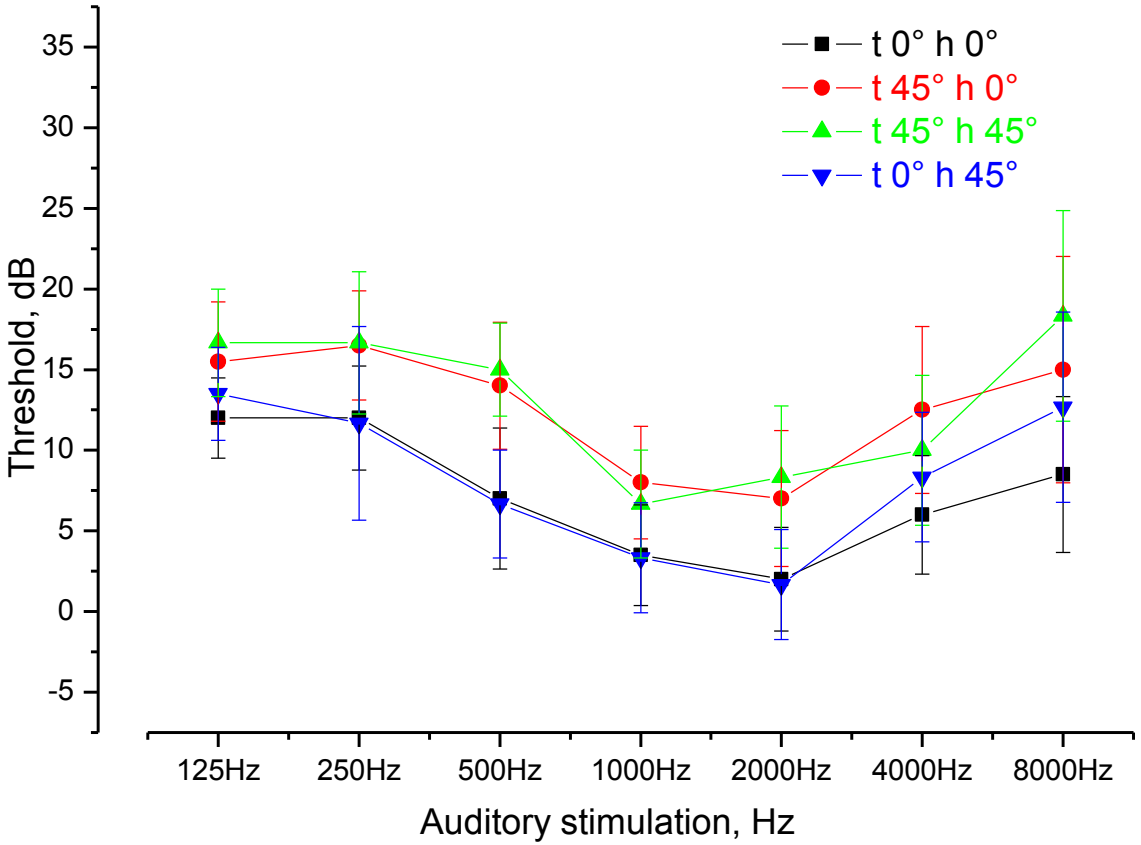
Conclusions: This finding suggests that the ability to locate acoustic targets in space during head movement depends not only on the auditory system, but also on the vestibular system. It seems that the vestibular signal, providing self motion information, is responsible for the correct dynamic of the target pursuit, since the acoustic system alone shows a significant delay in detecting sound position.

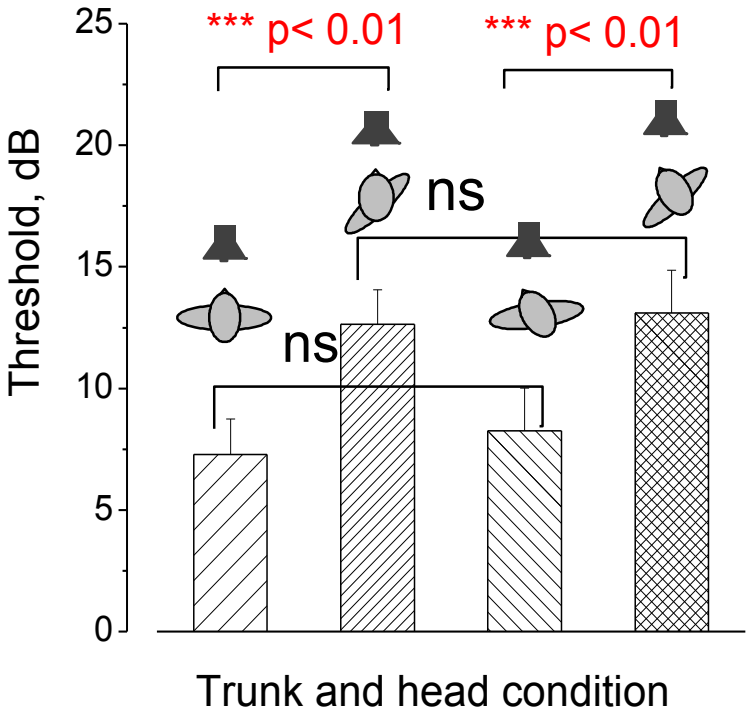
Asymmetrical and vestibular stimulations and tonal audiometry

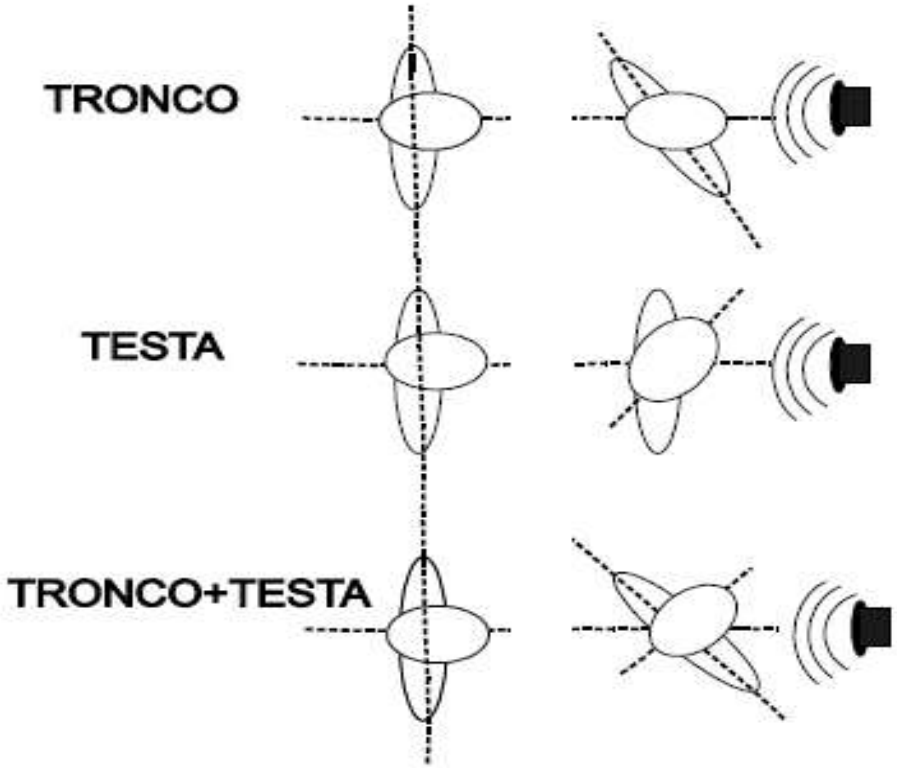


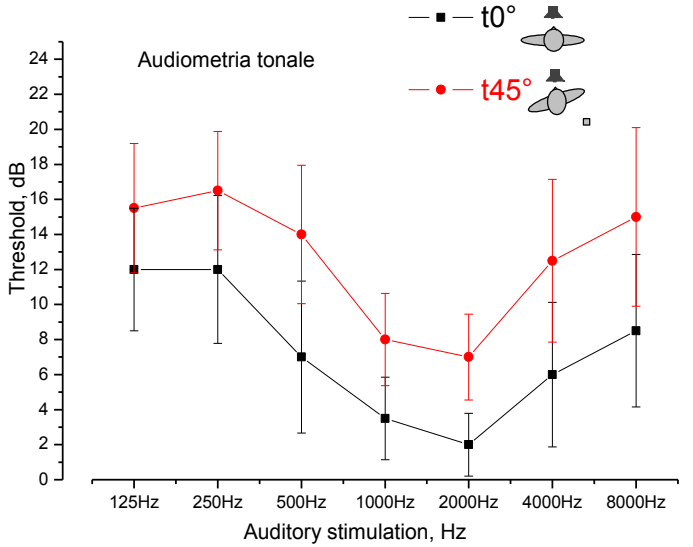


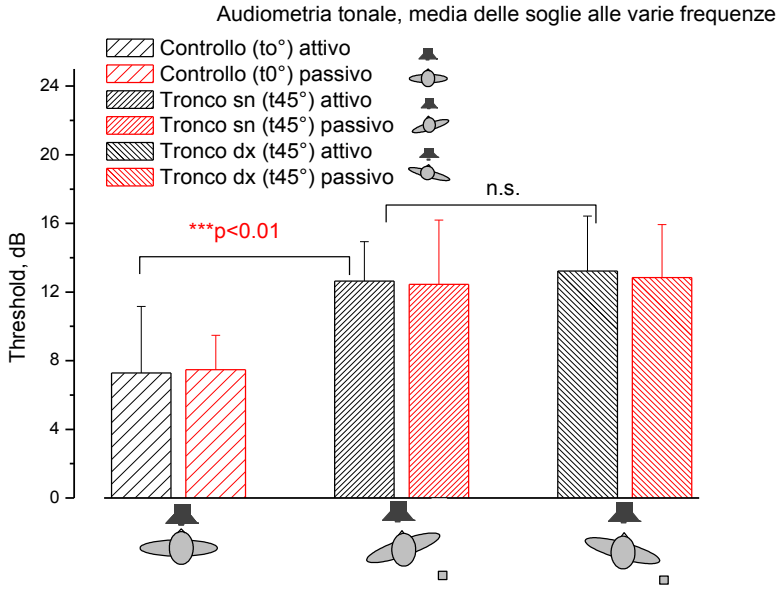
Role of the head and trunk position



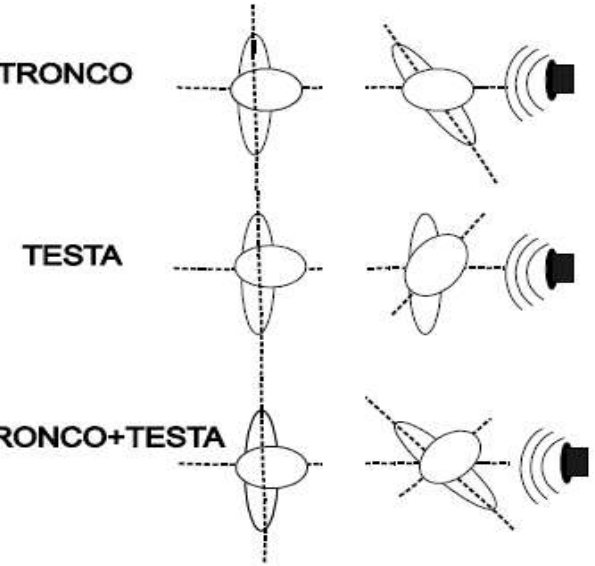


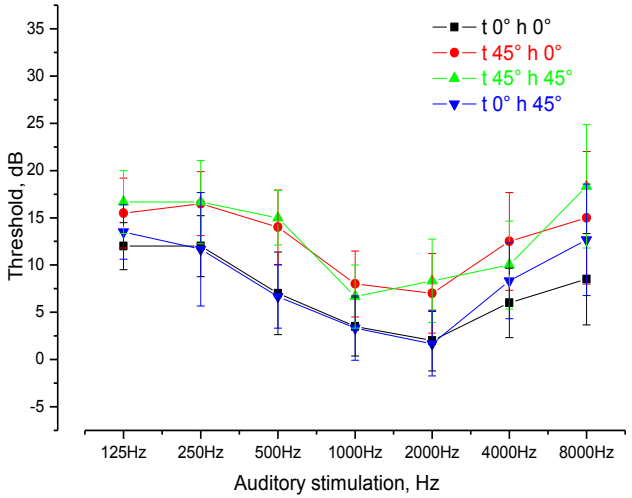

TRONCO
TESTA
TRONCO+TESTA

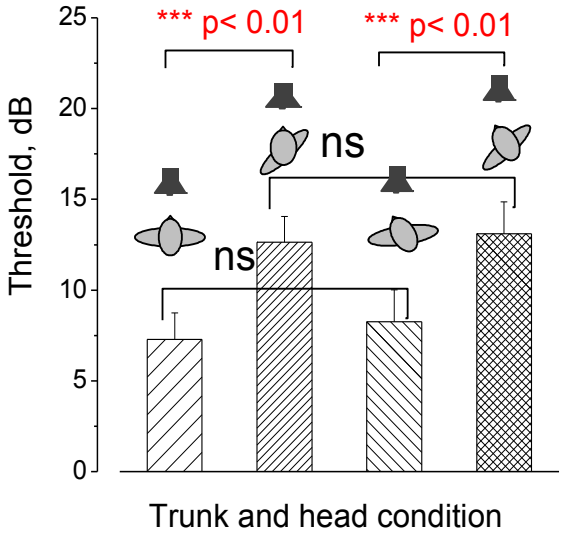

t0°
t45°
Audiometria tonale
Threshold, dB
0
2
4
6
8
10
12
14
16
18
20
22
24
125Hz
250Hz
500Hz
1000Hz
2000Hz
4000Hz
8000Hz
Auditory stimulation, Hz


Audiometria tonale, media delle soglie alle varie frequenze
Controllo (to°) attivo
Controllo (t0°) passivo
Tronco sn (t45°) attivo
Tronco sn (t45°) passivo
Tronco dx (t45°) attivo
Tronco dx (t45°) passivo
***p<0.01
n.s.
Threshold, dB
0
4
8
12
16
20
24

Body position influences acoustic threshold and acoustic target fixation or pursuit (Pettorossi et al.)



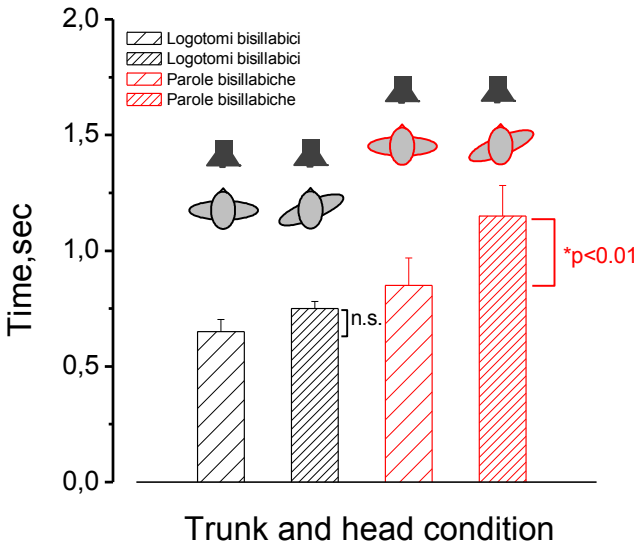




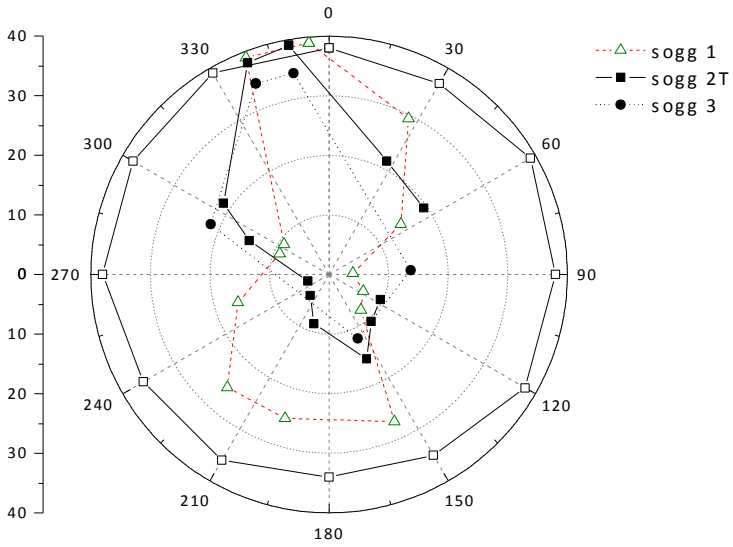
La soglia acustica è influenzata dalla posizione del tronco rispetto alla sorgente sonora:
Segnali vestibolari e propriocettivi modificano la sensibilità acustica

La posizione del tronco influenza la comprensione delle parole e l'inseguimento acustico

Comprensione sillabe



Inseguimento acustico



CONCLUSIONS:

THE ORIENTATION OF THE TRUNK TOWARDS SOUND STIMULATION LOWERS ACOUSTIC THRESHOLD SHIFT. THIS THRESHOLD DOES NOT VARY CHANGING THE POSITION OF THE HEAD ALONE.

Conclusioni

segnali acustici influenzano l'equilibrio?

Si

La percezione acustica è influenzata dal sistema vestibolare e propriocettivo?

Si

L'orientamento e l'equilibrio sono dunque il risultato delle informazioni sensoriali che originano dal sistema vestibolare, da quello visivo, quello propriocettivo e dal sistema acustico

Grazie per l'attenzione