The Analysis Of Sensory Reweighting Deficit In Parkinson's Disease During Standing

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BACKGROUND

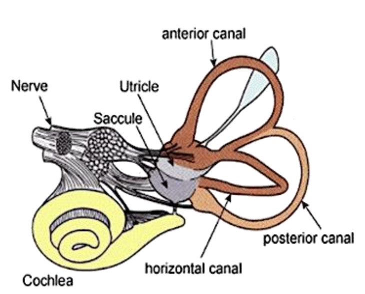
Control of human upright stance

Sensory input **from multiple sources** is necessary

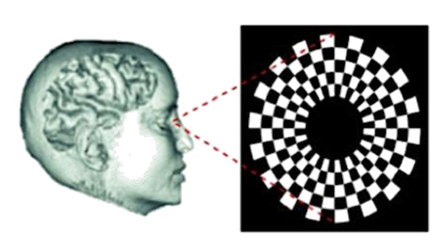
- ✓ to detect center of gravity excursions
- ✓ to generate appropriate muscle responses for upright stance control.

Visual, vestibular and proprioceptive modalities

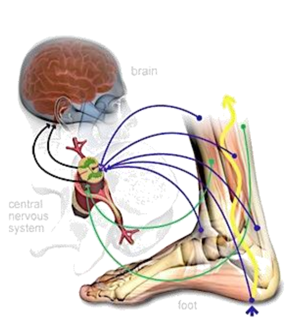
Estimation of body position/velocity (i.e., self-motion) **is heavily dependent upon the integration of information from multiple sensory modalities.**



vestibular modality



visual modality



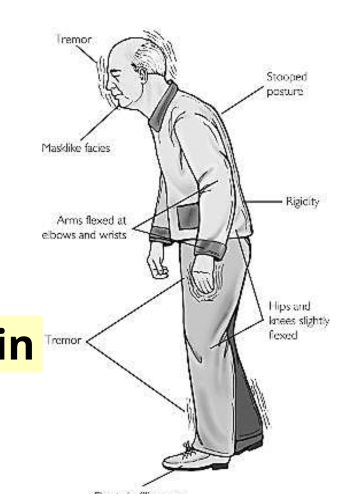
proprioceptive modality

Sensory reweighting

Sensory reweighting is the process through which the nervous system changes the "emphasis" of a particular sensory input due to neurological injury or when environmental conditions change.

Parkinson's Disease (PD)

Parkinson's Disease is a degenerative disorder of the central nerve system. **Deficits in proprioceptive are prevalent in individuals with PD.**



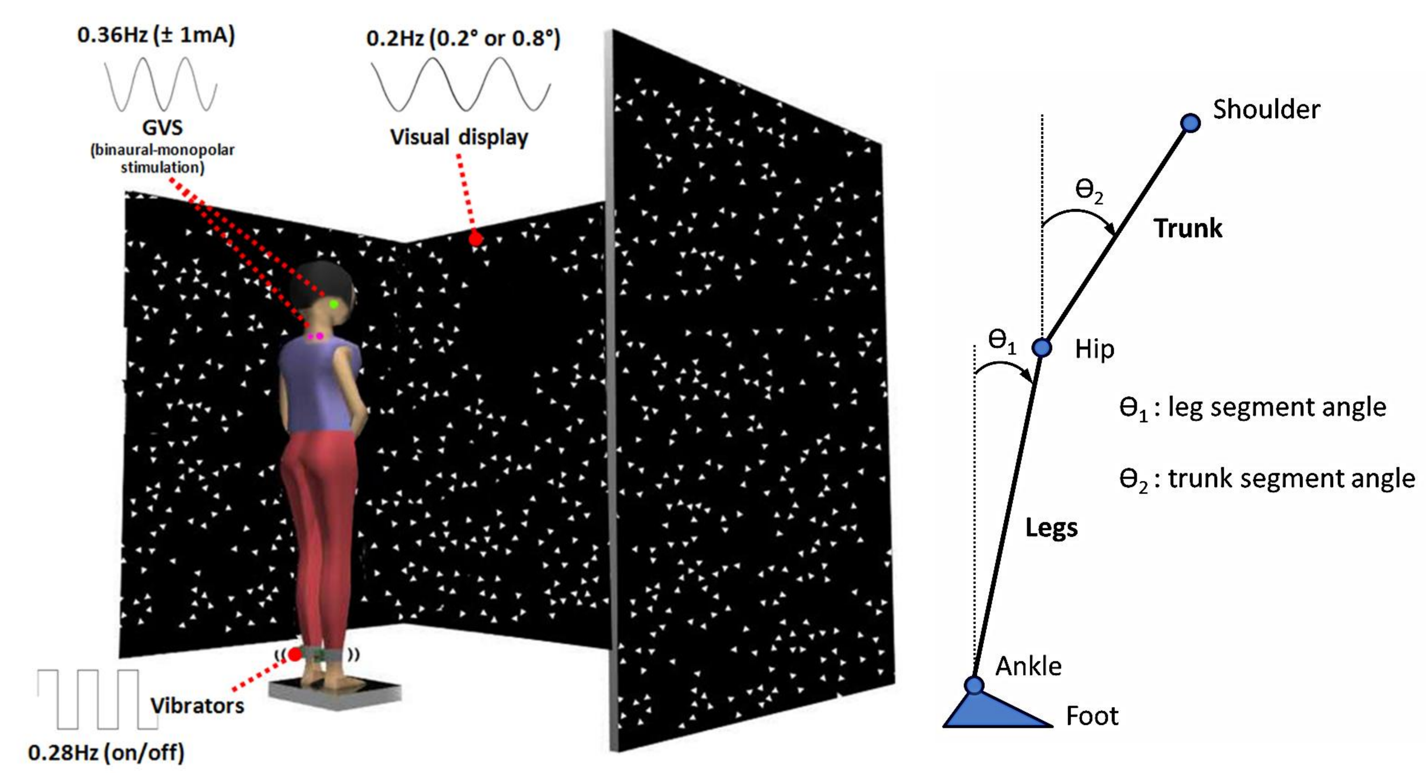
RESEARCH PURPOSE

Q: Are proprioceptive deficits in individuals with PD observed during standing ?

Q: Does proprioceptive deficits influence sensory fusion of multiple modalities in individuals with PD?

We **simultaneously perturbed visual, vestibular and proprioceptive modalities** to understand the interplay between all three modalities so that overall feedback remains suited to stabilize **upright stance in individuals with PD.**

METHODS



STIMULI

Visual stimulus

- 0.2 deg and 0.8 deg rotation (pitch) about ankle axis
- stimulus frequency : 0.2 Hz

Vibration

- 80Hz vibration at both Achilles' tendons
- on/off to approximate a square-wave periodic stimulus
- stimulus frequency : 0.28 Hz

Galvanic Vestibular Stimulation (GVS)

- binaural-monopolar GVS
- ±1mA sinusoidal galvanic stimulus
- stimulus frequency : 0.36 Hz

SUBJECTS:

10 healthy young participants *(28.2±4.6yrs)*
8 patients with PD *(66.3±8.6yrs, 3 PD stage 1, 4 PD stage 2, 1 PD stage 3)*

EXPERIMENT SETUP: 4 conditions, 135 sec/ trial, 5 trials in each condition

- **L-V-G** : low amplitude vision – vibration – GVS
- **L-G** : low amplitude vision – no vibration – GVS
- **H-V-G** : high amplitude vision – vibration – GVS
- **H-G** : high amplitude vision – no vibration – GVS

KINEMATICS: leg segment angle & trunk segment angle

ANALYSIS: Frequency response functions (FRFs)

- **The FRF, $H_{xy}(f)$, is the CSD divided by the PSD of the input.**
- **PSD** – power spectral density
- **CSD** – cross spectral density
- **Gain** : the absolute value of the FRF, $H_{xy}(f)$
- **Phase** : the argument of the FRF, $H_{xy}(f)$, converted to degrees

STATISTICAL ANALYSIS:

- **Two way repeated-measures ANOVA** *(for visual stimulus and GVS)*
  visual amplitude (low vs. high amplitude) × vibration *(vibration vs. no vibration)*
- **Maximum-likelihood method** *(for vibration)*

RESULTS

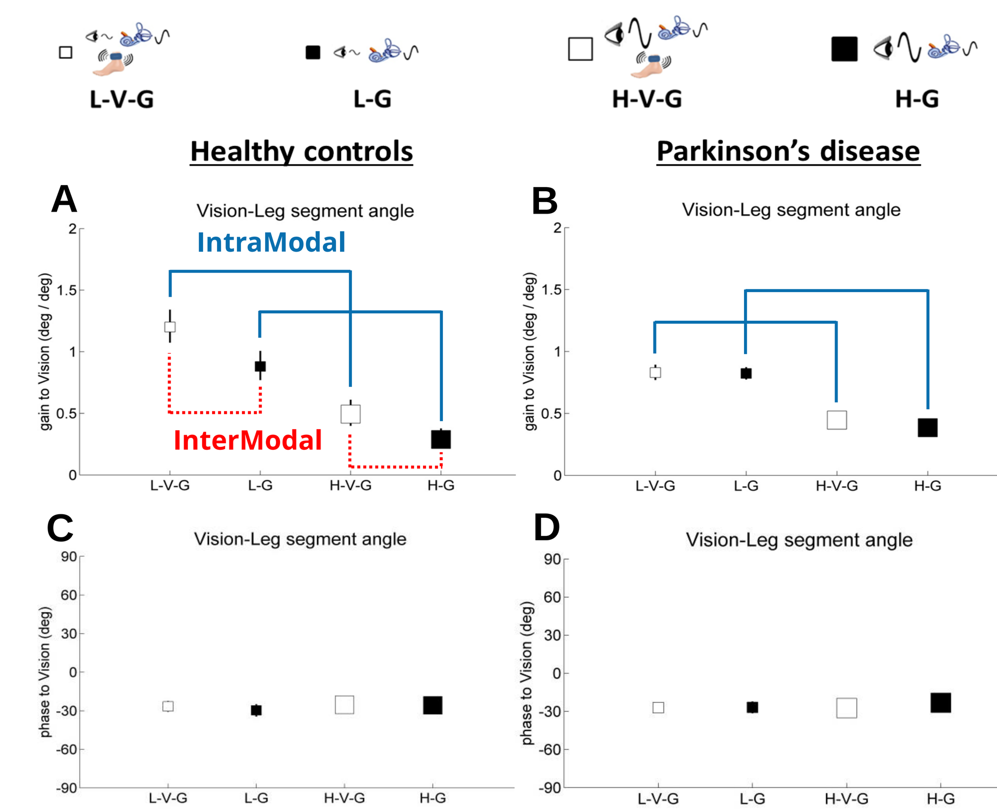


Figure 1. Gain and phase of segment angles relative to vision

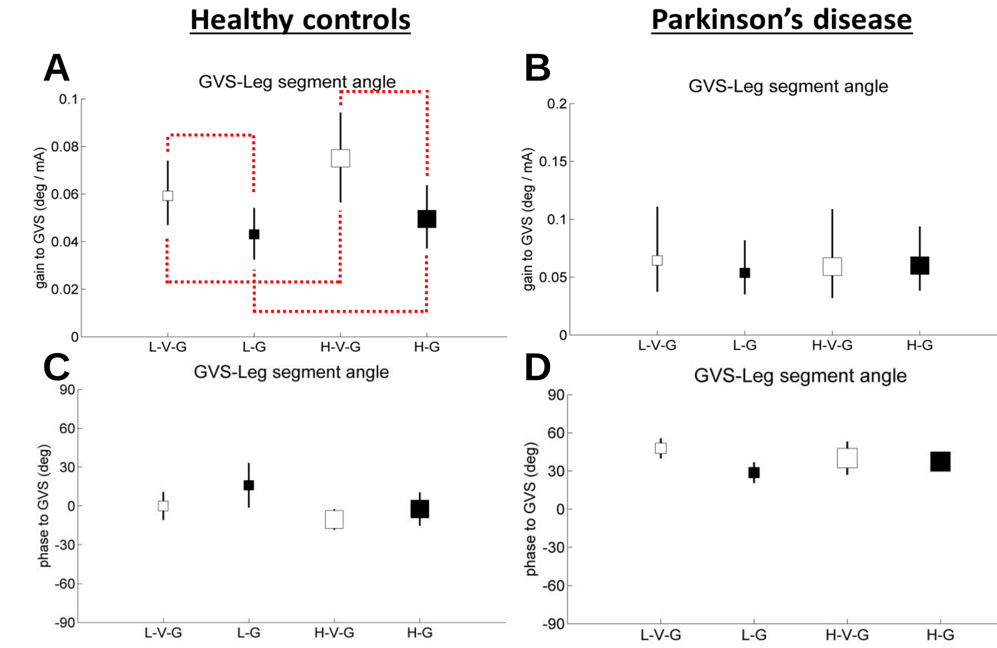


Figure 2. Gain and phase of segment angles relative to GVS

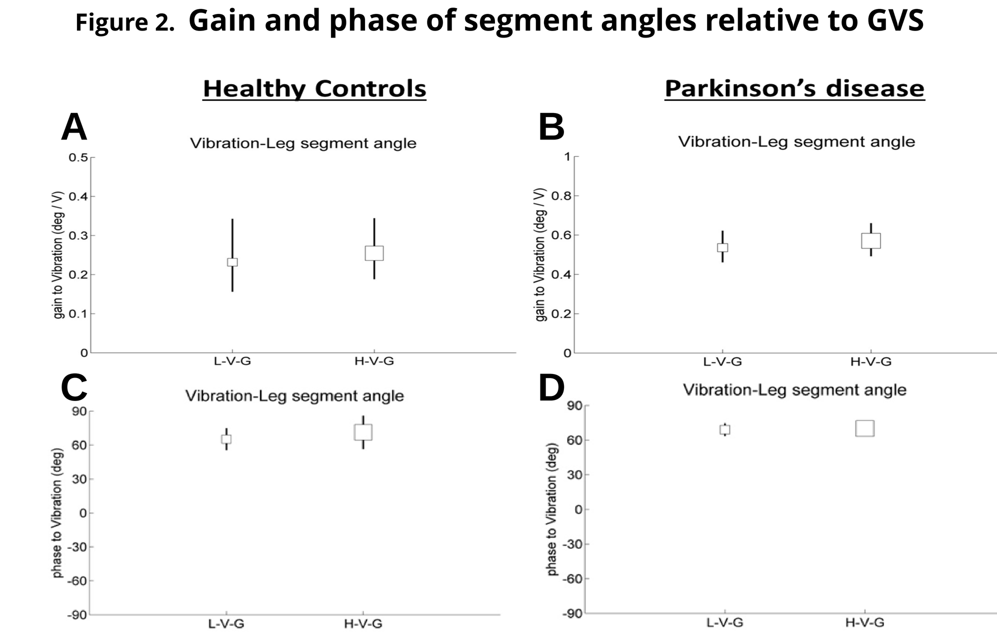


Figure 3. Gain and phase of segment angles relative to vibration

GAIN RESPONSES: Vision low to high amplitude

Conditions: **L-V-G to H-V-G** and **L-G to H-G**

Healthy controls

IntraModal Visual Downweighting *(Fig 1A)*
➡ decrease leg/trunk gain relative to vision

InterModal Vestibular Upweighting *(Fig 2A)*
➡ increase leg gain relative to GVS

- Reflects compensation for visual downweighting.

Parkinson's disease

IntraModal Visual Downweighting *(Fig 1B)*
➡ decrease leg/trunk gain relative to vision

No InterModal Vestibular Upweighting *(Fig 2B)*
➡ no effects on leg/trunk gain relative to GVS

- Reflects PDs' severe reweighting deficits in the vestibular channel.

GAIN RESPONSES: Vibration off to on

Conditions: **L-G to L-V-G** and **H-G to H-V-G**

Healthy controls

InterModal Visual Upweighting *(Fig 1A)*
➡ increase leg/trunk gain relative to vision

InterModal Vestibular Upweighting *(Fig 2A)*
➡ increase leg gain relative to GVS

- Reflects compensation for vibration by upweighting vision and vestibular information.

Parkinson's disease

No InterModal Visual Upweighting *(Fig 1B)*
➡ no effects on leg/trunk gain relative to vision

No InterModal Vestibular Upweighting *(Fig 2B)*
➡ no effect on leg/trunk gain relative to GVS

- Reflects PDs' severe reweighting deficits in the proprioceptive channel.

PHASE

- ✓ no differences across conditions
- ✓ absolute differences relative to modality

CONCLUSION

Results that individuals with **PD have severe reweighting deficits, not only in the proprioceptive channel**, as the literature suggests, **but in the vestibular channel as well.**

This deficit influences the cross-modal fusion of sensory information that is crucial for upright stance control.

More importantly, our paradigm is able to detect not just deficits in processing a single modality but is **able to detect deficits in fusing the different modalities, through intermodal effects.**

Possibly an age effect, but previous results have shown intact sensor fusion in older adults (Allison et al., 2006)

This is the first time, to our knowledge, that the interplay between the three primary modalities for postural control has been clearly delineated, illustrating a central process that fuses these modalities for accurate estimates of self-motion.

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