Effects of Immersive Visual Feedback Distortion on Step Length Symmetry Using Augmented Reality

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Introduction

Gait Asymmetry
- Caused by neurological disorders, injuries, and/or aging [1]
- Hinders mobility, balance, & energy efficiency [2], [3]

Visual Feedback Distortion (VD)
- Distorts visual feedback by misrepresenting step lengths [4]
- Enhances motor adaptation

Augmented Reality (AR)
- More interactive & engaging [5]
- Keeps feedback within view
- Reduces distractions

Purpose
- Evaluate the potential of AR-based VD (AR-VD) to improve rehabilitation outcomes & functional independence for individuals with gait asymmetry

Hypothesis
- AR-VD will lead to greater gait symmetry adaptation & longer-lasting aftereffects compared to monitor-based VD (M-VD)

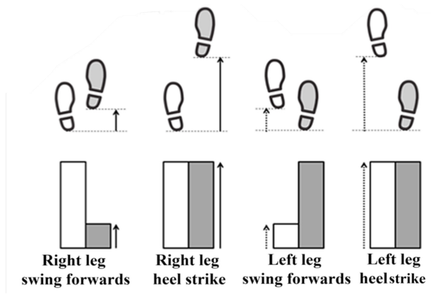
Methods

Protocol

1 Healthy Subject
- 1 M-VD session
- 1 AR-VD session

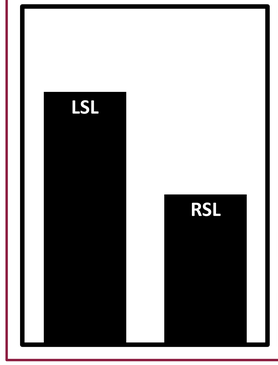
2 Visual Feedback (VF) Bars
- Right step length (RSL)
- Left step length (LSL)

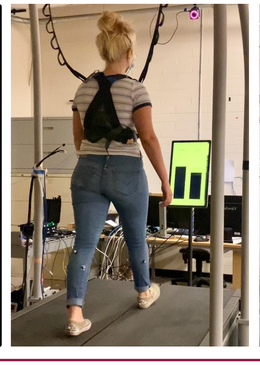
Step Length Symmetry
- LSL = RSL
- Equal bar heights at heel strike



MAIN TRIAL (21 min)

PHASE 1: Baseline	PHASE 2: Adaptation	PHASE 3: Post-Adaptation
Duration: 2 min	Duration: 10 min	Duration: 9 min
VF: undistorted	VF: distorted	VF: none
Task: match bar heights	Task: match bar heights	Task: keep gaze ahead





Methods

Visual Feedback Distortion (VD)
- Subjects uninformed of distortions
- Each minute for first 5 minutes of adaptation phase:
  - Increase VD by 3%
  - Decrease RSL bar height by 3% of actual RSL

⇧ % VD
⇩ RSL bar
⇧ Actual RSL
⇧ SSR
⇩ Symmetry

Data Analysis

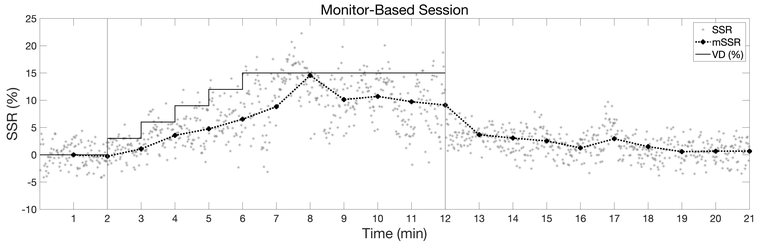
Step Length Symmetry Ratio (SSR)
- Calculated for each gait cycle

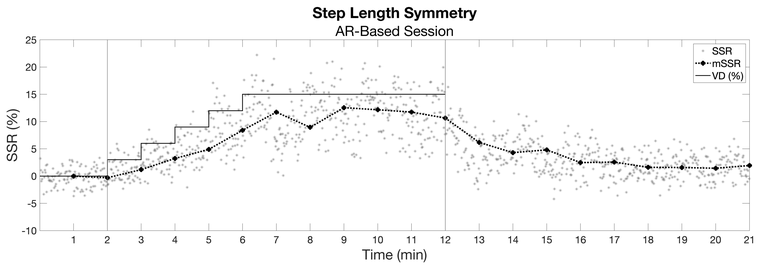
Mean SSR (mSSR)
- Average SSR each minute of trial

$$SSR(\%) = \frac{RSL - LSL}{\frac{1}{2}(RSL + LSL)} \times 100$$

Results

Between Phases





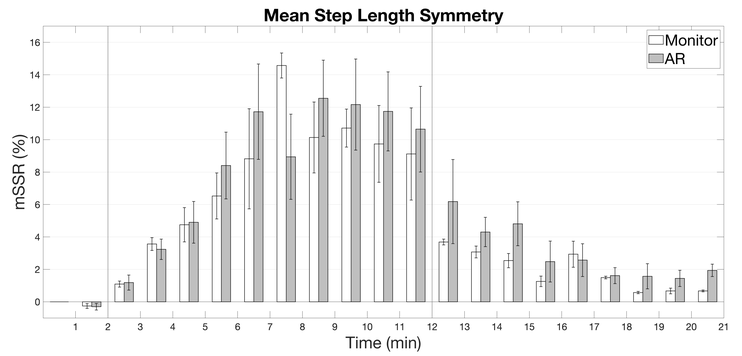
1. Baseline Phase
- mSSR ≈ 0% → RSL ≈ LSL
- Roughly symmetric gait

2. Adaptation Phase
- SSR > 0% → RSL > LSL
- Develops asymmetric gait
- ↑ % VD, ↑ mSSR

3. Post-Adaptation Phase
- mSSR > 0% → RSL > LSL
- Maintains asymmetric gait
- Smaller mSSR than in adaptation phase
- Larger mSSR than in baseline phase

Results

Between Sessions



1. Baseline Phase
- Natural gait for healthy subject

2. Adaptation Phase
- Generally larger mSSRs with AR-VD
  - Stronger motor adaptation
  - Suggestive of increased engagement

3. Post-Adaptation Phase
- Generally larger mSSRs with AR-VD
  - Stronger aftereffects
- Slower mSSR decay with AR-VD
  - Longer aftereffect retention
  - Suggestive of increased immersion

Conclusions and Future Directions

Initial results suggest AR-VD leads to greater gait symmetry adaptation & longer-lasting aftereffects compared to M-VD
- AR-VD holds potential to improve rehabilitation outcomes & functional independence for individuals with gait asymmetry

Future Directions:
- ↑ sample size
- Incorporate metric to quantify subject engagement
- ↑ session duration
- Implement for individuals with gait asymmetry

References

[1] A. R. Anwary, H. Yu, and M. Vassallo, "An automatic gait feature extraction method for identifying gait asymmetry using wearable sensors," *Sensors (Basel)*, vol. 18, no. 2, 2018.

[2] H. Sadeghi, P. Allard, F. Prince, and H. Labelle, "Symmetry and limb dominance in able-bodied gait: a review," *Gait & Posture*, vol. 12, no. 1, pp. 34–45, Sep. 2000, doi: https://doi.org/10.1016/s0966-6362(00)00070-9.

[3] S. Viteckova, P. Kutilek, Z. Svoboda, R. Krupicka, J. Kauler, and Z. Szabo, "Gait symmetry measures: A review of current and prospective methods," *Biomed. Signal Process. Control*, vol. 42, pp. 89–100, 2018.

[4] S.-J. Kim and H. I. Krebs, "Effects of implicit visual feedback distortion on human gait," *Experimental Brain Research*, vol. 218, no. 3, pp. 495–502, Mar. 2012, doi: https://doi.org/10.1007/s00221-012-3044-5.

[5] H. Thikey, M. Grealy, F. van Wijck, M. Barber, and P. Rowe, "Augmented visual feedback of movement performance to enhance walking recovery after stroke: study protocol for a pilot randomised controlled trial," *Trials*, vol. 13, no. 1, p. 163, 2012.

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