Utilizing Interlimb Coupling with Mirrored Deficit Fields for Enhanced Bilateral Arm Movement

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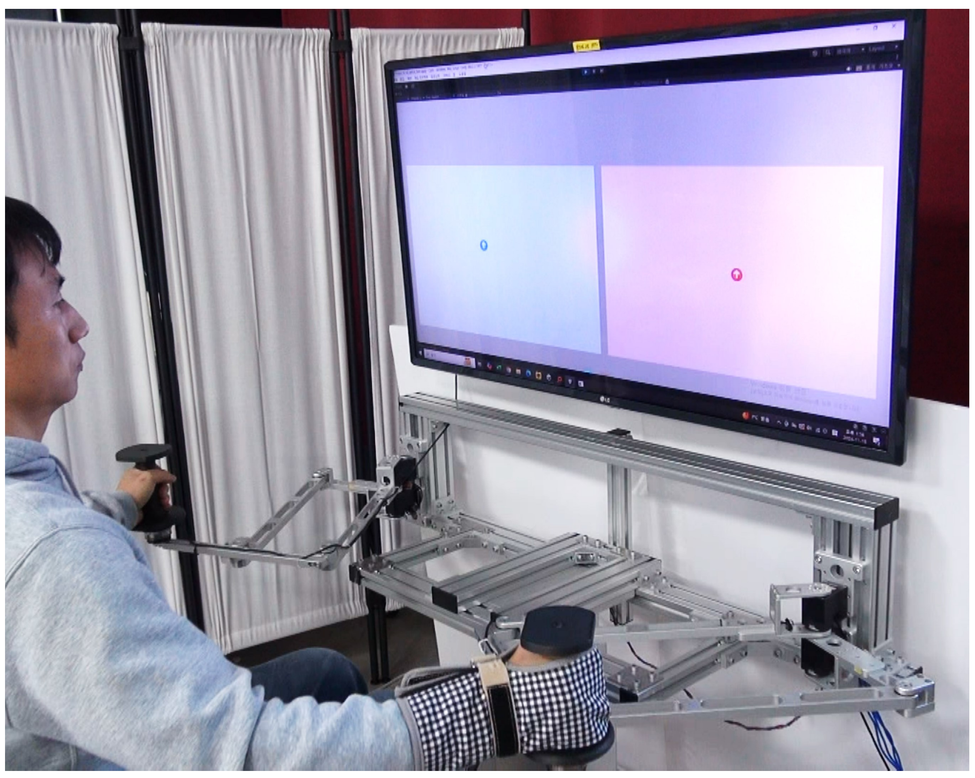
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Introduction

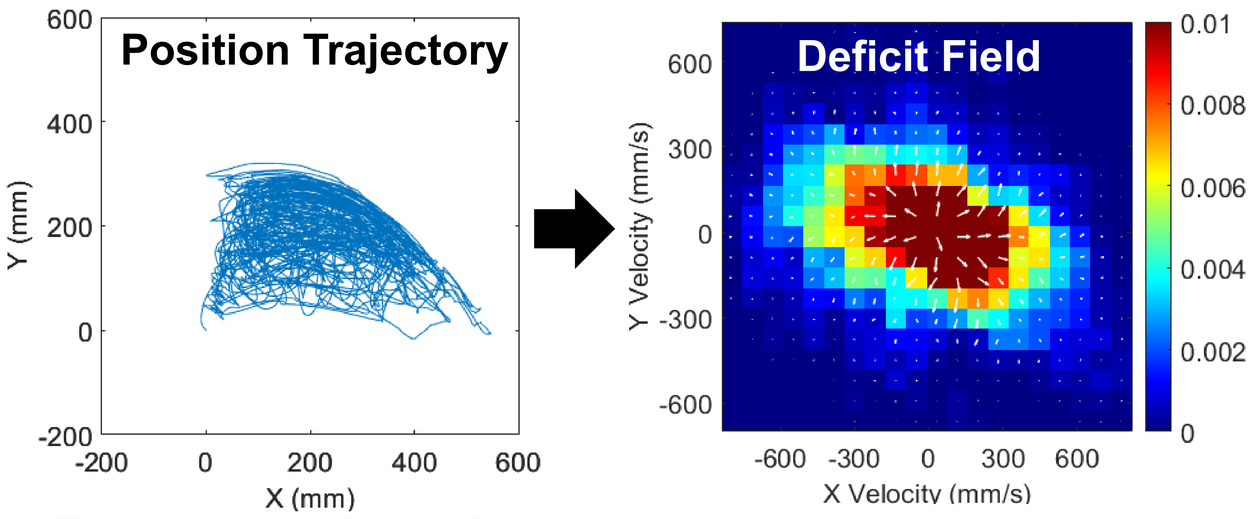
- **Post-stroke participants** performed **free exploration** with their **affected arm** to generate **a personalized Deficit Field (DF)** from **velocity profiles**.
- The **DF** was applied to the **affected** arm, the **unaffected** arm with **mirrored** parameters, or **both arms** to examine its effects on bimanual coordination and movement exploration.

Methods

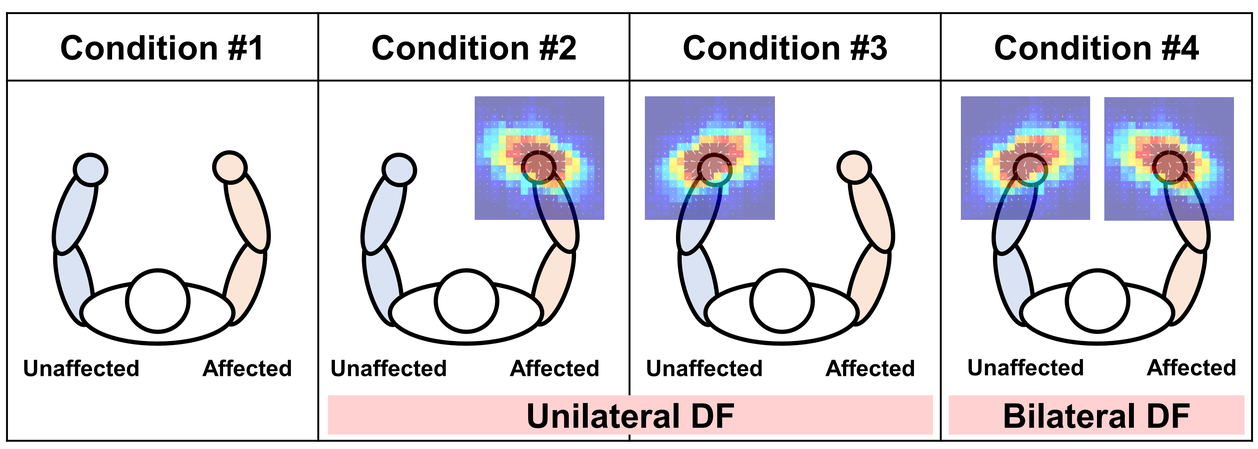
- **Participants:** 6 with chronic stroke, 5 able-bodied
- **NREH-Bimanual Robotic Platform** (Song, 2023; Lee & Song, 2024)
  - Custom 2D bimanual robotic arm system delivering DF-based force perturbations.



- **Deficit Field (DF):** generated by computing the gradient of the normalized velocity distribution obtained from free exploration, directing forces toward underexplored movement regions (Wright et al., 2015; Wright et al., 2017).

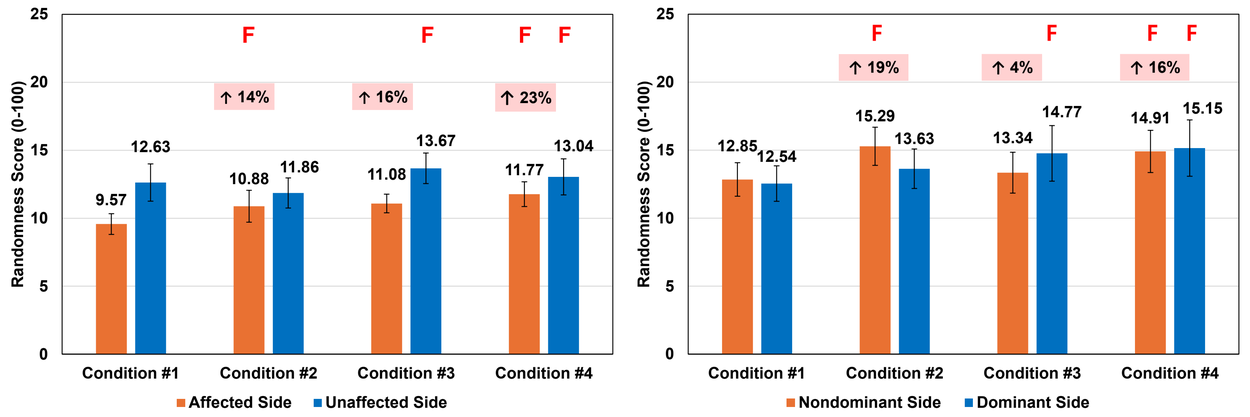


- **Experimental Procedure**
  - Participants completed 4-min Free Exploration using the affected (or non-dominant) arm
  - Velocity data were collected to generate personalized DF.
  - 4 Experimental Conditions (2 min each + 2 min rest)

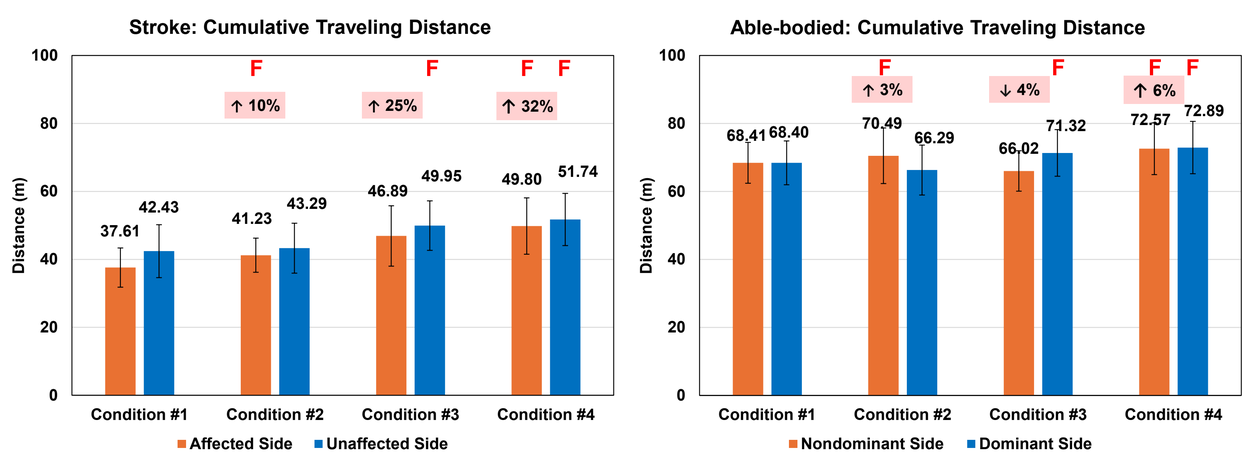


Result

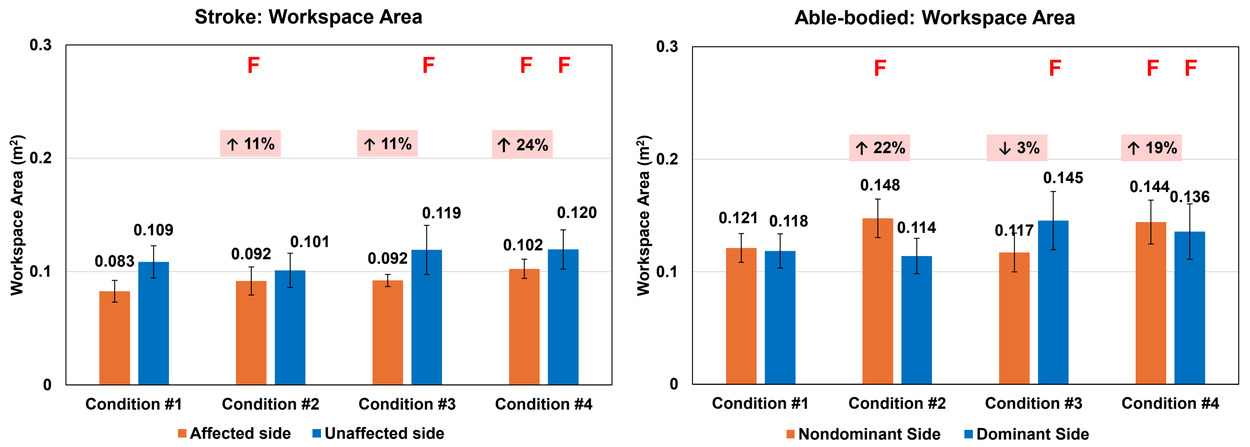
- **Randomness Score (0-100):** **Higher values indicate more varied directions and speeds, reflecting better movement exploration and motor learning.**
  - **(Stroke)** DF on the unaffected arm increased RS on the affected side more than DF on the affected arm.
  - **(Able-boded)** RS increased on the DF-applied side, and bilateral DF reduced RS differences between arms.



- **Cumulative Traveling Distance (m):** **Total arm movement distance. Greater values suggest higher activity and faster average speed during the task.**
  - **(Stroke)** A similar pattern to RS, and the differences in CTD were more pronounced.
  - **(Able bodied)** Unilateral DF reduced CTD on the opposite arm, while bilateral DF promoted more balanced engagement across both arms.



- **Workspace Area (m^2):** **Area covered by arm movement (based on convex hull). Larger area implies wider range of motion and improved reach.**
  - **(Stroke)** Workspace on the affected side expanded most with bilateral DF, showing progressive improvement across conditions.
  - **(Able bodied)** Unilateral DF led to asymmetric changes, while bilateral DF promoted workspace expansion on both sides, especially the dominant side.



Discussion & Conclusion

- **Mirrored DF** application enhanced **movement exploration** and **bimanual coordination**.
- This effect was most notable when **DF was applied to the unaffected or both arms**, leveraging **interlimb coupling mechanisms**.
  - ✓ Interlimb coupling allows one arm's movement to influence the other through shared neural pathways. In this study, mirrored force fields on the unaffected arm improved the affected arm's performance, supporting this effect (Arya & Pandian, 2014; Hascher et al., 2023; Cauraugh & Summers, 2005).
- These findings support its potential as an **effective rehabilitation strategy for stroke patients**.

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