Development of a Virtual Reality Gamified Training to Promote Bimanual Skills for Myoelectric Prosthetic Pediatric Users with Limb Difference

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Introduction

- Children with upper-limb differences tend to abandon prostheses due to discomfort, limited functionality, and lack of engagement [1]
- Traditional rehabilitation exercises fail to maintain motivation because they can be seen as repetitive and disconnected from daily life [2]
- Research shows that gamified training improves EMG control and engagement [3, 4]
- VR environments enable immersive practice of functional tasks with immediate feedback [5]
- Bilateral coordination is essential for daily independence [6]

This project develops a VR gamified training system that uses bimanual tasks and progress tracking to improve prosthetic adoption and functional outcomes for children with upper-limb differences.

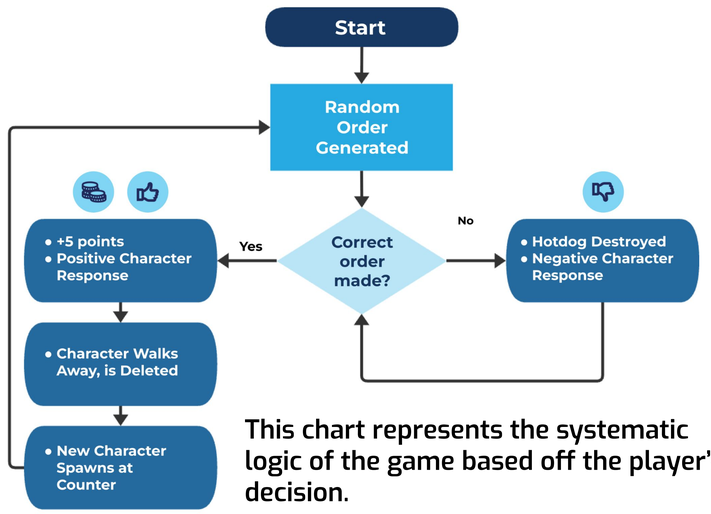
Methodology

Meta Quest 3 Headset | **Standard Controllers** | **EMG Flex Controller**



This VR gamified training system includes the surface electromyography "flex" sensor, and leverages three assessment methods:

- Score
- User Satisfaction Survey [7]
- Voice Affirmed "Concurrent Think-Aloud" protocol [8]



This chart represents the systematic logic of the game based off the player's decision.

Results

Below is the the Unity based VR game environment, showing the gameplay, with a randomly generated order and character along with the setting of the hotdog building station.
The player will complete bimanual tasks, using the EMG and standard controller in conjunction, such as building the hot dog and adding condiments. The fundamental motion primitives for preparing a hot dog are reaching, grasping rotating, and placing.



FLEX:
☐ LIMB LOADING ☐ ARM-AS-CONTROLLER

GYRO:
☐ LIMB LOADING ☐ ARM-AS-CONTROLLER

FLEX & GYRO:
☐ LIMB LOADING ☐ ARM-AS-CONTROLLER

BIMANUAL TASKS: FLEX & GYRO
☐ LIMB LOADING ☐ ARM-AS-CONTROLLER

Conclusion

Gamified training provides a low-stress environment that has the potential to encourage bilateral coordination essential for real-world activities. This type of gamified training expands the available prosthesis trainings to include a spatial skills learning opportunity in a fun VR setting.





This VR system and pipeline provides bimanual task simulation, limb loading, and progress tracking to increase engagement for pediatric prosthesis training.

Future Work

- Integrate limb-loading and prosthetic-as-controller pipeline
- Integrate customizable virtual prosthetic
- IoT-enabled progress monitoring
- Conduct user studies to evaluate effectiveness
- Create various levels



Representation of future bionic limb integration

Acknowledgements and References

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[1] R. Collu, E. Ferrazzano, V. Murgia, C. Salis, and M. Barbaro, "The Technological and Psychological Aspects of Upper Limb Prostheses Abandonment: A Narrative Review," Prosthesis, vol. 7, no. 6, p. 167, Dec. 2025, doi: 10.3390/prosthesis7060167.

[2] T. Sims, M. Donovan-Hall, and C. Metcalf, "Children's and adolescents' views on upper limb prostheses in relation to their daily occupations," British Journal of Occupational Therapy, vol. 83, no. 4, pp. 237–245, Apr. 2020, doi: 10.1177/0308022619865179.
[3] A. Tabor, S. Bateman, and E. Scheme, "Evaluation of Myoelectric Control Learning Using Multi-Session Game-Based Training," IEEE Trans. Neural Syst. Rehabil. Eng., vol. 26, no. 9, pp. 1680–1689, Sep. 2018, doi: 10.1109/TNSRE.2018.2855561.
[4] C. Prahm, F. Kayali, A. Sturma, and O. Aszmann, "PlayBionic: Game-Based Interventions to Encourage Patient Engagement and Performance in Prosthetic Motor Rehabilitation," PM&R, vol. 10, no. 11, pp. 1252–1260, Nov. 2018, doi: 10.1016/j.pmrj.2018.09.027.
[5] B. N. Perry et al., "Virtual Integration Environment as an Advanced Prosthetic Limb Training Platform," Front. Neurol., vol. 9, p. 785, Oct. 2018, doi: 10.3389/fneur.2018.00785.
[6] M. S. Ardon et al., "Relationships Among Manual Body Functions, Manual Capacity, and Bimanual Performance Using the Prosthetic Upper Extremity Functional Index in Children With Congenital Hand Differences," Physical Therapy, vol. 94, no. 6, pp. 767–775, Jun. 2014, doi: 10.2522/ptj.20130209.
[7] J. Brooke, "SUS – a quick and dirty usability scale," 1996, pp. 189–194.
[8] A. Pellicone et al., "Playing Aloud: Leveraging Game Commentary Culture for Playtesting," International Journal of Gaming and Computer-Mediated Simulations, vol. 14, no. 1, pp. 1–16, Mar. 2022, doi: 10.4018/IJGCMS.296705.