Virtual Reality Display Influences Dynamic Movement Patterns in Gaming-Based Research

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Introduction

• Gaming in virtual reality is increasingly being investigated as a clinical tool to promote movement and rehabilitation.
• The purpose of this study was to determine if the type of display used in a virtual reality (VR) game affected the movement patterns used in performing a kinematically redundant dynamic task.

Methods

• Participants
  - Seventeen subjects (10 male, 7 female) aged 18-35 played the same VR dodging game under two different display conditions.

• Test Conditions
  - Condition 1: 3D-TV Presentation
    - In the 3D-TV display, the subject wore 3D shutter glasses and was oriented to the avatar in the first-person perspective (Fig. 1A, 1B).
  - Condition 2: Oculus Rift® Presentation
    - In the OR display, the subject wore a head mounted display and was oriented to their avatar in the first-person perspective (Fig. 1C, 1D).

• Order of display was randomized for each subject.

• Gameplay
  - Thirty virtual balls were launched at the subjects during each round. Subjects scored points by successfully positioning the virtual ball in both hands to intercept each launched ball.
  - The tasks required both appropriate joint excursions and the correct timing of these excursions to block the launched ball.
  - The tasks required dynamic movement.
  - The tasks allowed redundant movement solutions for successful completion.
  - The impact locations were scaled to the anthropometrics of each subject to normalize the amount of virtual lumbar flexion required to block each launched ball (Fig. 2, 3). For each subject, the impact locations of the launched balls were randomized, but identical for the games played in each display.

• Analysis
  - The kinematics, as measured with Vicon-Bonita cameras, Vicon Tracker, and The MotionMonitor were defined by angular excursions between a median plane and postural position at time of intercept of the launched ball.
  - Measures
    - Excursions of the ankle, knee, hip, lumbar spine, and elbow were analyzed.
    - Position of the center of the hands at intercept of the tracked ball was tracked.

• Statistical Analysis
  - Mixed-model (main effects of display: 2D-TV vs. 3D-TV) ANOVA was performed with display (2D-TV vs. 3D-TV) as a within-subject factor and as an between-subject factor.

Results

• There were no significant main effects of display on any of the dependent variables.

Conclusions

• The tasks allowed redundant movement solutions for successful completion.
• The theoretical model of inducing precise lumbar motions through targeting hand positions is insufficiently robust for this dynamic, kinematically redundant task, and a better model is needed for future research seeking to induce lumbar motion with virtual dodgeball gameplay.

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Figure 1: Visual representations of the game. A) Individual playing game on 3D-TV while controlling avatar in first-person view. B) Participant’s third-person view of avatar on the 3D-TV. C) Participant’s first-person view in Oculus Rift. D) Individual playing game while wearing the Oculus Rift headset with scene duplicated on the TV.

Figure 2: Theoretical framework for selecting the impact locations of each round of gameplay. Five impact heights (IH) were chosen spanning the distance from the head to the height to the lowest impact location determined by a theoretical amount of lumbar flexion.

Figure 3: Range of impact locations for each of the levels. Levels corresponded to the lowest targets requiring no lumbar flexion and 15, 30, and 60 degrees of lumbar flexion.

Figure 4: Launched ball trajectories for a single level of the game.

Figure 5: Hand position at time of ball contact for all games for all subjects shown in the sagittal plane. A) Results of the game played on the 2D-TV. B) Results of the game played on the Oculus Rift. Trials that were successfully blocked are colored in corresponding to the degree of lumbar flexion that was utilized at the time of ball contact. The origin is set to the center of medial malleolus of the ankle. Significant differences were shown between the two displays for anterior hand displacement at contact (p ≤ 0.05).

Figure 6: The effect of display type on joint excursions at each impact height (RH) collapsed across game levels, body parts, and hand position. A) Ankle (B) Knee (C) Hip (D) Lumbar spine E) Shoulder F) Elbow NS = not significant. Unless noted by NS, all differences were significant (p ≤ 0.05).