

# Designing Multisensory VR Games for Enhancing the Health of Older Adults

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Simultaneous declines in visual function (e.g., dynamic visual acuity, DVA), cognitive ability (e.g., cognitive control/multitasking), and physical function (e.g., balance) are common symptoms of aging that impact synergistically on the daily lives of older adults. These functions are not only closely linked but also have significant impacts on independence in performing basic daily living tasks and in maintaining the quality of life. On the other hand, immersive virtual reality (VR) technology not only has the unique value of health intervention but also effectively facilitates the combination and synergy of these multisensory modalities.

However, existing intervention approaches (e.g., traditional cognitive/physical training, DVA training, video games, and VR games) are designed to account for cognitive ability (cognitive modality) or physical function (physical modality), or a combination of both, while overlooking one crucial sense modality, which is DVA function for older adults. Considering the potential and synergistic impacts available in integrating dynamic vision, cognitive, and physical modalities to assist older adults, we consider neglect of the potential of all three modalities when designing digital health interventions (e.g., cognitive enhancement) for older adults to be unreasonable.

Therefore, this dissertation proposes a multisensory (multimodal) integrated approach. This approach integrates DVA, cognitive, and physical modalities into an engaging, interesting, and immersive VR environment. This dissertation aims to explore and validate this innovative health intervention approach in the effect of enhancing the health of older adults. To achieve this, this dissertation is structured into two parts. Part I reviews theoretical studies on a multisensory integrated approach, introducing the relationship among DVA, cognitive and physical modalities, and the unique value of VR based on a literature review (Chapter 2), and identifies the design characteristics and potential synergistic impact of multisensory in current VR gaming systems (Chapter 3). Part II focuses on empirical studies, presenting the design mechanism and empirical evidence for the acceptability of our multisensory VR game (Chapter 4) and exploring the effect of the multisensory VR game on DVA, cognitive, and physical health for older adults (Chapter 5).

Building on these works, we observed that:

- (1) Current VR games integrating cognitive and physical modalities show diverse designs, but none focus on dynamic visual acuity, with only two incorporating dynamic visual stimuli. However, incorporating dynamic visual stimuli suggests potential synergistic benefits across modalities.
- (2) The synergistic multisensory game design is highly accepted by older adults and provides greater benefits for them compared to young adults. It also highlights the advantages of multisensory VR games over traditional cognitive interventions, such as PC-based cognitive tasks, in supporting older adults.
- (3) Our multisensory VR game training shows the positive potential impacts on dynamic visual acuity, the processing speed in response inhibition, static balance, and lower limb strength.

(4) The synergistic value of the multisensory (multimodal) integration approach is also identified in this dissertation.

The main contributions of this dissertation are as follows:

(1) Introducing a novel health intervention perspective: we propose the multisensory integration approach as a new method for health interventions.

(2) Developing an innovative VR game system: we present the first multisensory VR game system that synergistically integrates cognitive, physical, and DVA modalities. The findings offer empirical evidence supporting the acceptability of such systems for older adults.

(3) Demonstrating long-term benefits: through a long-term intervention experiment, it provides the first empirical evidence of the effectiveness of multisensory VR game training in enhancing cognitive, physical, and DVA health among older adults.

(4) Conducting a groundbreaking systematic review: the systematic review in this dissertation is the first to focus specifically on this field, offering a unique motivational perspective on multimodality in VR games for older adults.

(5) We identified the synergistic value of the multisensory (multimodal) integration approach.

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