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Effect of viewing angle on arm reaching while standing in a virtual environment: Potential for virtual rehabilitation

K.I. Ustinova [a,b,*], J. Perkins [a,b], L. Szostakowski [a,b], L.S. Tamkei [b], W.A. Leonard [b]

[a] Department of Physical Therapy, Central Michigan University, MI, USA
[b] College of Health Professions, Central Michigan University, MI, USA

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ABSTRACT

Functional arm movements, such as reaching while standing, are planned and executed according to our perception of body position in space and are relative to environmental objects. The angle under which the environment is observed is one component used in creating this perception. This suggests that manipulation of viewing angle may modulate whole body movement to affect performance. We tested this by comparing its effect on reaching in a virtually generated environment. Eleven young healthy individuals performed forward and lateral reaches in the virtual environment, presented on a flat screen in third-person perspective. Participants saw a computer-generated model (avatar) of themselves standing in a courtyard facing a semi-circular hedge with flowers. The image was presented in five different viewing angles ranging from seeing the avatar from behind (0°), to viewing from overhead (90°). Participants attempted to touch the furthest flower possible without losing balance or stepping. Kinematic data were collected to analyze endpoint displacement, arm-postural coordination and center of mass (COM) displacement. Results showed that reach distance was greatest with angular perspectives of approximately 45–77.5°, which are larger than those used in analogous real world situations. Larger reaches were characterized by increased involvement of leg and trunk body segments, altered inter-segmental coordination, and decreased inter-segmental movement time lag. Thus a viewing angle can be a critical visuomotor variable modulating motor coordination of the whole body and related functional performance. These results can be used in designing virtual reality games, in ergonomic design, teleoperation training, and in designing virtual rehabilitation programs that re-train functional movement in vulnerable individuals.

1. Introduction

Reaching for an object while standing is an essential component of numerous daily life activities. These activities are planned and executed according to an individual's visual perception of body position in space and relative to the object (Bernstein, 1967; Gibson, 1954; Lashley, 1930). In turn, this perception is the result of integration and interpretation of multiple visual control variables, with the angle under which the object is observed playing an essential role. Research has determined that angle of view can modulate processing in multiple brain areas involved in planning and preparing object-related voluntary movements (Baker, Donoghue, & Sanes, 1999; Bédard, Thangavel, & Sanes, 2008; DeSouza, Dukelow, & Vilis, 2002). Altering the angle can affect a participant's estimation of distance to an object (Gardner & Mon-Williams, 2001; Levin & Haber, 1993; Mon-Williams, McIntosh, & Milner, 2001) and alter the isometric muscle force a participant applies to an object (Vaillancourt, Haibach, & Newell, 2006). These findings suggest that by artificially altering viewing angle it may be possible to influence the performance of functional body movements such as reaching while standing.

Testing this possibility is important in light of growing interest in incorporating virtual reality simulations and computer games into rehabilitation programs for individuals with the risk of falling and incurring injuries during functional activities. Virtual reality (VR) technologies provide an opportunity for visual manipulation and repeated practice in a controlled safe environment (Rand, Kizony, & Weiss, 2004; Sveistrup, 2004). Almost any environment can be generated virtually and presented using different perspectives and angles to address participants' needs and rehabilitation goals. There is, however, little research on precisely how altering viewing perspectives can improve dynamic characteristics of movements.

In recreation and training applications of virtual reality, visual perspective, frequently referred as point of is an important characteristic. Participants can view the virtual world as if seen through

* Corresponding author. Address: Doctoral Program in Physical Therapy, Central Michigan University, Mt. Pleasant, MI 48859, USA. Tel.: +1 989 774 2699; fax: +1 989 774 2789.
E-mail address: ustin1k@cmich.edu (K.I. Ustinova).

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their own eyes (first-person view), or they can view the world as if watching themselves through a camera, usually positioned somewhat above and behind (third-person view). The fully immersed or first-person view is thought to increase a participant's sense of virtual presence and immersion, but at the risk of increasing side effects such as nausea (Crosbie, Lennon, McNeill, & McDonough, 2006). In contrast, the third-person view is less immersive, but may be preferred for some recreation gaming (Salamin, Thalman, & Vexo, 2006) and rehabilitation applications (Rand et al., 2004; Yavuzer, Senel, Atay, & Stam, 2008) as a less expensive and more practically applicable approach.

The second important variable in a virtual rehabilitation is the angle of view. In a virtual environment, the visual scene can be represented from different angles. Some VR applications allow angular adjustment of the image relative to the head position. In others this cannot be done, and an individual is then limited to one particular presentation of the image. A real world remains constant and observing it in different viewing angles changes both the eye position and image projection on the eye retina, and normally reflects a change of position of the viewer. In contrast, a simulated environment is usually adjusted to the individual. In this environment eye movements in the orbits are minimal and accommodation is constant. Consequently, a participant is deprived of an important part of real world efferent information and proprioceptive feedback from extraocular muscles, and must rely mainly on retinal input. When performing motor skills in VR, it is important to determine the best viewing perspective and angle to facilitate motor performance. This question has not been investigated in a systematic way.

One possibility is that the effect of viewing angle in a virtual environment will be similar to that observed in the real physical world. There it has been shown that presentation of an object under an oblique angle rather than directly in line with the eyes can facilitate reading a book (Schmidt, Ullrich, & Rossner, 1993; Shieh & Lee, 2007), improve productivity of flight operators (Turville, Psihogios, Ulmer, & Mirka, 1998), and even reduce postural oscillations while standing (Kapoula & Lê, 2006). These results may be relevant to arm-postural coordination performed in the virtual environment and to fine-tuning virtual reality presentations for optimal performance. The purpose of this study was to determine how changes in viewing angle alter a functional arm movement performed in standing. In this study when we discuss viewing angle we refer to the angle defined by two vectors, the first vector being a horizontal line originating at the target of the reach and projected parallel to the ground, and the second being the line connecting the target with the spot where the virtual camera used to present the scene is positioned, making this a third-person version of the real world gaze angle (Fig. 1). As an experimental task, participants performed reaching forward and laterally while standing in a virtually generated garden presented on a flat screen using a third-person view. These movements are part of many daily tasks such as gardening, grocery shopping, doing laundry, etcetera. They also resemble the Functional Reach tests commonly used to predict fall risk and to track rehabilitation progress for individuals at risk of falling, due to age or illness, when performing functional activities (Duncan, Weiner, Chandler, & Studenski, 1990; Takahashi et al., 2006; Weiner, Duncan, Chandler, & Studenski, 1992).

2. Methods

2.1. Participants

A volunteer sample of eleven healthy young adults (10 female, 1 male) with a mean age of 24.2 years (range = 22–25) participated in the study. All signed informed consent documents approved by the facility Institutional Review Board and in compliance with the Declaration of Helsinki. Participants had no known visual or perceptual problems, movement impairments or other conditions that would place them at increased risk of falling. Nine individuals reported and were observed to be right-hand dominant and two were left-hand dominant.

2.2. Experimental procedure

The experimental task consisted of reaching forwards and laterally in a virtual environment presented to participants on a

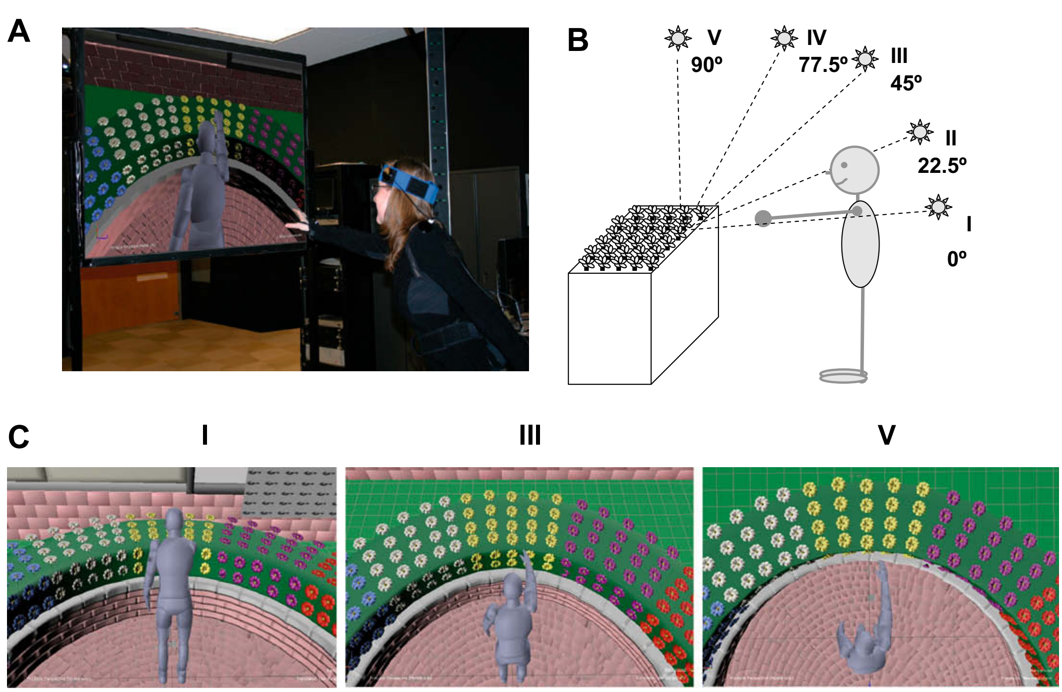

Fig. 1. (A) A participant faces the screen and views the computer-generated representation of herself (avatar) in the center of a patio surrounded by a hedge covered with colored flowers. (B) Schematic figure illustrating viewing angles from I to V. (C) Visual images presented to participant under viewing angles I, III, and V.