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Effectiveness of virtual reality using Wii gaming technology in children with Down syndrome

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ABSTRACT

This quasi-experimental study compared the effect of standard occupational therapy (SOT) and virtual reality using Wii gaming technology (VRWii) on children with Down syndrome (DS). Children ($n = 105$) were randomly assigned to intervention with either SOT or VRWii, while another 50 served as controls. All children were assessed with measures of sensorimotor functions. At post-intervention, the treatment groups significantly outperformed the control group on all measures. Participants in the VRWii group had a greater pre–post change on motor proficiency, visual-integrative abilities, and sensory integrative functioning. Virtual reality using Wii gaming technology demonstrated benefit in improving sensorimotor functions among children with DS. It could be used as adjuvant therapy to other proven successful rehabilitative interventions in treating children with DS.
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1. Introduction

Down syndrome (DS) is a chromosomal anomaly that leaves the individual affected with an additional chromosome (the 21th). The syndrome is associated with approximately 1/800 live births and is one of the leading causes of intellectual disabilities (Roizen, 2002).

Children with DS are characterized by delays in motor milestone attainment, sensorimotor performance deficit, and perceptual dysfunctions, in addition to significant limitations both in intellectual functioning and in adaptive behavior (Burack, Hodapp, & Zigler, 1998; Hogan, Rogers, & Msall, 2000). One of the most established findings is that children with DS are slower at both initiating and executing goal-directed movements compared to typically developing peers (Savelsbergh, van der Kamp, Ledebt, & Planinsek, 2000). They also exhibit greater movement time advantages as the accuracy demands of the movement goal are increased (Hodges, Cunningham, Lyons, Kerr, & Elliott, 1995). Commonly reported sensorimotor deficits exhibited by children with DS also include perceptual-motor slowness (Elliott & Bunn, 2004), limb control problems (Anson & Mawston, 2000) and decreased motor proficiency (Wuang, Lin, & Su, 2009). Besides, children with DS demonstrate very specific movement problems when they are required to organize a sequence of movement on the basis of verbal information (Heath, Elliott, Weeks, & Chua, 2000). The specific verbal-motor difficulties have implications for motor skill instruction. These sensorimotor difficulties may hinder their participation in school activities, academic performance, independence in daily living, and social acceptance by peers (Hamilton, 2002; Pivik, McComas, & Laflamme, 2002). Effective therapy to enhance sensorimotor function is thus of paramount importance in facilitating integration into daily life, and reducing the immediate burden and future expense on the society (Wuang & Niew, 2005).

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The most effective traditional approaches for treating sensorimotor problems in children with DS include sensory integrative (SI) therapy, the perceptual-motor (PM) approach, and neurodevelopmental treatment (NDT) (Wuang, Wang, Huang, & Su, 2009). SI intervention is based on the premises that sensory input is necessary for optimal function for the child's brain and that early intervention will promote underlying capabilities and minimize abnormal function as a result of plasticity in the central nervous system that is greatest during early childhood (Ayres, 1989). SI therapy is justified in the treatment of children with DS, since a common feature in this group of children is a failure to integrate sensory information into adaptive responses that include making judgments about the environment, responding to the environmental challenges with success and accomplishing the required role imposed by the occupation (Ayres, 2004). The PM approach assumes a causal relationship between motor behavior and underlying perceptual processes. PM training provides the child with an array of experiences with sensory and motor tasks via therapist-directed structured activities. General improvement in perceptual and academic abilities is anticipated as a consequence of enhanced sensory and motor experiences (Cratty, 1981). PM approach treatment of children with DS has a long history reflecting the incidence of perceptual motor deficits (such as specific visual–perceptual disturbances and learning difficulties) (Batshaw & Shapiro, 2002; Hoover & Wade, 1985), and continues to be the treatment of choice for many clinicians (Wallen & Walker, 1995). The NDT frame of reference focused on understanding children's difficulties related to muscle tone, stability, and, mobility and implements targeted interventions to address these areas of difficulty (Schoen & Anderson, 1999). NDT is appropriate for use in children with DS because these children often present with accompanying neuromuscular dysfunction (i.e., hypotonia, unusual posture, poor limb control, atypical muscle activation; Adams, Chandler, & Schulmann, 2000; Bar-Haim et al., 2006; Butler & Darrah, 2001).

However, traditional therapies for movement difficulties in children with disabilities are repetitive and offer very little to keep a young mind occupied (Adamovich, Fluet, & Merians, 2009). Besides, children with disabilities tend to show difficulty in repeated practice of functional activities because of the nature of their disabilities (i.e. movement limitation, attention deficit, or cognitive impairments) or a lack of intervention context variability (Taub, Ramey, DeLuca, & Echols, 2004; Wuang, Wang, Huang, & Su, 2009). Interactive virtual reality (VR) can provide a much wider array of activities and scenarios for movements. Virtual reality (VR) is defined as a means to a user–computer interface that consists of real-time environmental simulation, that is, the users could interact with the scenario or environment via multiple sensory channels (Burdea, 2003). VR could create an exercise environment in which the practice intensity and positive sensory feedbacks (i.e. auditory, visual, and proprioceptive) can be manipulated systematically in different natural-like environments to allow for individualized motor training programs (Wilson, Foreman, & Stanton, 1997). Therefore, plenty of experimental evidence suggests that rapid advancement of VR technologies has great potential for the development of novel strategies for sensorimotor training in rehabilitation (Adamovich et al., 2009).

Neuroplasticity refers to the ability of brain structures to change. There is an abundance of research that supports the concept of neuroplasticity in pediatric rehabilitation since neuronal organization and integration can take place through participating types of purposeful activities used in therapeutic intervention (Ayres, 2004; Barthel, 2010; Kramer & Hinojosa, 2010; Mulligan, 2002; Parham & Mailloux, 2010), particularly through the mirror-neurons systems, including areas of frontal, parietal, and temporal lobes in the human brain, which increase their firing rates when children observe movements performed by other persons (Buccino, Solodkin, & Small, 2006; Rizzolatti & Fabbri-Destro, 2008). The gaming industry has developed a variety of VR systems for home use, making this technology both affordable and accessible with potential application in community settings (i.e., children' school, classroom, therapy room). The novel VR gaming systems could provide for massive and intensive sensorimotor stimulation to activate mirror-neuron systems needed to induce brain reorganization by allowing the children to interact in 3 dimensional scenarios and observe the avatar movements captured on the screen simultaneously (Buccino et al., 2006; Saposnik et al. 2010). Besides, the discrepancies between the real and virtual feedback introduced in VR gaming system could activate targeted brain networks which is crucial for motor learning (Adamovich et al., 2009).

In recent studies of patient with stroke, investigators started incorporating commercially available video games (Nintendo Wii) into their treatment regimen and the results verified the treatment effect (Saposnik et al., 2010). However, to date, no evidence is available on the effectiveness of an interactive virtual reality gaming system in children with intellectual disabilities, so there is a legitimate need to evaluate effect of VR in this population. Thus, we hypothesized that virtual reality using Wii gaming technology (VRWii) is potentially efficacious in enhancing sensorimotor functions compared to standard sensorimotor training among children with DS.

2. Method

2.1. Participants

The study was conducted during 2009–2010 in the pediatric occupational therapy unit, Department of Rehabilitation Medicine, of the university affiliated medical center, after approval by its ethics committee. Inclusion criteria included (1) aged between 7 and 12 years; and (2) a diagnosis of DS determined by the board-certified physicians at local designated hospitals. Excluded were children who carried coexisting autism, cerebral palsy, blindness, and deafness in an attempt to minimize confounding of data. Also excluded were children with previous history of neurological disorders such as traumatic brain injury, muscular dystrophies, and epilepsy.

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