The role of occupational therapy in assessing alternative access to augmented reality for individuals with complex motor profiles

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INTRODUCTION

Augmented Reality (AR) is an interactive technology in which digital information can be projected onto the physical world with the ability for a user to participate in a multi-sensory experience [1]. It allows for a controlled, safe experience, with a minimal amount of set-up and equipment to engage in activities that once required more complex technical devices and environmental modification [2]. Over the last decade, AR interaction techniques and user interfaces have become more affordable and accessible. This has resulted in a growing number of users available to trial this technology for applications related to education, telecommunications, gaming, and medicine [3]. The increased prevalence of tablets such as iOS devices (e.g., iPads) in the consumer marketplace results in far greater exposure of this technology, as tablets can serve as an interface for AR applications. While AR has been designed with the general population in mind, modifications to access and application of the technology is easier to accomplish than ever before. As AR becomes increasingly available as a mainstream technology, with specific accommodations it should provide individuals with complex motor profiles access to therapeutic, educational, play, leisure, and social participation opportunities. Occupational therapists (OTs) are uniquely suited to determine which supports will enable these individuals to engage in successful use of AR.

OTs are skilled in the evaluation of motor patterns and functional participation. Activities of importance are analyzed to assess the physical, cognitive, visual, and psychological requirements of a specific task [4]. This client-centered evaluation highlights where there are breakdowns in successful activity performance – a process often referred to 'feature – matching'. Further, this provides the information necessary to recommend specific assistive devices and technology, or make modifications to an individual's environment to support improved performance [5]. With complex knowledge of body structures and functions and the importance of participation for psychological well-being, OTs are ideally suited to provide the necessary recommendations to ensure individuals who evidence diverse physical abilities are able to access AR applications on tablet-based systems.

RELATED RESEARCH

Within the field of OT, AR has been tried primarily with adults in small clinical trials to determine if it is a feasible intervention in a clinical setting as an upper limb neuromuscular rehabilitative tool [6]. As AR is a new and potentially breakthrough technology and one that does not have associated stigma as a recovery tool, it is not surprising that individuals are motivated to try this technology. Engagement in motivating, enjoyable, and purposeful activities (e.g., gaming) as a means of intervention and daily use has been shown to enhance self-confidence, a sense of control, and lead to greater coping skills for everyday life [7]. It is important that the psychological benefits of increased participation be available to individuals outside of the first year of recovery after a significant medical event. After completing a thorough search of the literature, a paucity of research was found regarding the use of AR with individuals with ranging motor abilities, including those with a physical disability related to congenital, hereditary, and acquired disorders (e.g. cerebral palsy, autism, down syndrome, spina bifida disorders, arthrogryposis) [8]. Studies related to these disorders primarily focused on the use of AR for emotional regulation, improving facial expression recognition and response, and to teach multi-step task completion through forward chaining [9], [10], [11]. In each of these investigations, modifications for direct selection to the AR interface were not utilized because the subject who participated in these research studies did not require access modifications in order to interact with technology in their daily lives or instruct a caregiver to complete or facilitate physical tasks on their behalf.

COMMON BARRIERS AND SOLUTIONS TO AR INTERACTION

Through clinical practice as an OT at Boston Children's Hospital within the Augmentative Communication Program, the most common barriers to AR access on a tablet-based system were identified through interview, evaluation, and clinical case discussion. The following cases demonstrate examples of individuals who successfully used AR following recommendations for (a) operating system touch accommodations, (b) use of alternative cursor control, and (c) modifications to the task or environment through the use of physical tools.

Barrier 1: Necessity of environmental modifications and positioning supports

I.J. is a 10yo who participates in ongoing treatment sessions related to use of AR as a means to learn symbolic play skills. She presents with a short attention span, hyperactivity, and ambulates within the room with supervision. At times she wanders but she returns to the iPad to make intermittent selections and interact with physical play supports. Because she often pushes her iPad off the table while attempting to make selections, the need to realign the iPad with therapeutic AR visual markers is often required.

Solution 1: Mounting Equipment

A clamp-on mounting system was recommended to position the iPad in a consistent location through the AR experience. This prevent iPads from being damage when pushed to the floor or dropped because of decreased coordination or challenging behaviors. In addition, a mounting system affords the therapists the ability to better observe and interact with the learner, as iPad does not need to be held in place. For most systems, customization is not required. Considerations when purchasing a mount for AR-based therapeutic interactions include: 1. ensuring the mount does not occlude the rear camera, 2. Allowing sufficient length to position the iPad to project information onto a visible tabletop surface, 3. Being able to quickly reposition as content changes, 4. Being able to withstand moderate force so that the mount will not move when a target is directly selected. For table mounting options that are recommended to support use of AR in the clinical settings see Table 1.

Table 1. Tablet mounting solutions for clinical AR use

$	Modular Hose Loc-Line	Most affordable, easy to reposition, least secure against force
$$	AbleNet Friction Knob Universal Mounting System	Moderately priced, requires 2 hands to reposition, very secure against force
$$$	Rehadapt VarioFloat	Highest cost, moves in a gravity eliminated plane, easiest to reposition

Additionally, the use of a stable mounting system benefits wheeled mobility system users who want to engage in AR applications that interact with stimuli in a changing environment (e.g., “AR Runner,” “Pokemon Go”). Mounting a tablet or phone provides increased device safety and security not only to prevent damage, but also to prevent theft in community settings. Mounting eliminates the motor performance skills needed to manipulate an iPad and maneuver a wheelchair. Consistent device positioning can support AR participation with greater independence in multiplayer, social AR applications.

Barrier 2: Decreased fine motor coordination/strength

K.G is a 17yo with hypotonia, and has difficulty isolating his digits when reaching towards tablet screens and frequently makes accidental item selections. He is unable to access applications using direct selection without modifications.

Solution 2: iOS 13 based supports and/or use of styli

Direct Touch Accommodations

iOS built-in touch accommodations provide solutions for inaccurate direct selections due to decreased fine motor coordination, tremor, repetitive selections, or reduced upper extremity strength and range of motion. AR applications do not have in-application physical and motor setting accommodations. Participants must rely on iOS accessibility settings to interact with chosen AR applications. Commonly recommended iOS touch accommodations are described in Table 2 with associated affected client factors that require intervention for successful iOS use.

Table 2. iOS 13 Touch Accommodations

iOS Touch Accommodation	**Accommodation Description**	**Affected Client Factors & Performance Skills**
First Touch	Registers a selection as the first place touched on the screen. A user can touch the first point on screen and slide their hand off screen to select.	Reduced muscle strength, tremor, motor stereotypy
Last Touch	Registers a selection as the last place touched on the screen. A user can slide their hand across the screen and lift to select.	Reduced muscle strength, reduced muscle endurance
Hold Duration	The screen does not recognize a selection as intentional input unless the user holds their touch for a specific length of time	Tremor, motor stereotypy, reduced fine motor coordination

Ignore Repeat	The screen will not register multiple touches in a quick succession when performing a touch gesture	Reduced control of voluntary movement/Tremor, repetitive selections
Reachability	In portrait mode, items from the top half of the screen are brought down to the lower half of the screen after performing a gesture	Reduced range of motion, reduced fine motor coordination

Styli

Often a stylus is introduced when the participant experiences difficulty directly selecting a target on the touchscreen with an extended finger. There are several options for holding a stylus, as well as different models that can be used with limited or no fine motor skills. Styli can be comfortably worn on a user's digits, hands, wrists, forearms, or head. Use of a stylus can be a beneficial solution to providing AR access with or without the additional use of direct touch accommodations. Since a single point accesses the screen at a time, individuals who have difficulty with finger isolation will not accidentally touch areas of the screen.

Barrier 3: Inability to directly access the screen using touch selection

T.W., age 19, evidences spastic quadriplegia, with dystonia and decreased functional use of his upper extremities to independently participate in activities of daily living. He verbally directs caregivers and peers during leisure activities but expresses frustration and decreased interest in social engagement because he cannot manipulate items.

Solution 3: Alternative Mice and Cursor Control

If upper extremity motor coordination, strength, and tone limit an individual's ability to use direct touch and cannot be accommodated for, use of mouse support provides another opportunity for selection. iOS 13 introduced the option for mouse control through Assistive Touch settings enabling trackballs, mice, trackpads, joysticks, and head mice to be connected to Apple devices through a wired USB or Bluetooth connection. Alternative mice were trialed on an iPhone X, iPad, and an iPad Pro using a wired USB connection (Apple USB Camera Adapter) and Bluetooth connection (Figure 1) to assess the feasibility of accessing AR applications with similar success as compared to direct selection. Use of these supports provided an alternative method of accessing popular applications such as "SnapChat" and "Instagram", which features AR filters, which require sustained tapping on specific points to record video and gestures to flip through filters. Assistive Touch settings can be adjusted not only to best fit a user's individual needs, but also the task demands of AR participation. Mouse support settings that may be recommended for modification include mouse speed, cursor size, dwell speed, and use of custom gestures. Further, the Drag Lock setting makes interaction with AR applications that require the manipulation and dragging of items across the screen possible.

	iPhone X	iPad 9.7 (6th Gen)	iPad Pro 12.9 (3rd Gen)	Access
Accessory needed (wired USB)	Lightning to USB	Lightning to USB	USB-C to USB	
Head Mouse Nano	*Yes, but only with software update	*Yes, but only with software update	Yes	Switch connection on HMN receiver, or Dwell
Quha Zono	Yes	Yes	Yes	Switch connection on USB receiver, or Dwell
Trackball & Mice	Yes	Yes	Yes	Can map different buttons (ex. shortcuts, gestures, control)
Quad Joy 3	No	No	No	Shows as a cursor, but sip/puff selections not functional
Integra Mouse (Wired USB)	No, requires too much power	No, requires too much power	Yes	Using USB wired connection Pre-set actions: (Sip): Selection (Puff:) Assistive Touch Menu
Integra Mouse (USB Receiver)	Yes	Yes	Yes	Using Wireless USB Bluetooth Connection Pre-set actions: (Sip): Selection (Puff:) Assistive Touch Menu
AbleNet Tracker Pro (Wired USB)	No, requires too much power	No, requires too much power	Yes	Using USB wired connection Switch connection on Tracker receiver, or Dwell
Lipstick	Yes	Yes	Yes	Using USB wired connection, option for bluetooth connection Pre-set actions: (top tap) assistive touch menu (bottom tap) selection
Bluetooth connection				
GlassOuse	Yes	Yes	Yes	Built-in bluetooth Switch connection on headset, or Dwell

Figure 1. Pairing alternative mice to iOS devices

DISCUSSION AND IMPLICATIONS FOR PRACTICE

As AR becomes increasingly available as a mainstream technology, it can provide individuals with complex motor profiles access to therapeutic, educational, play, leisure, and social participation opportunities. OTs can determine

what supports are necessary for these individuals to engage in successful use of AR. It is becoming more and more apparent that that access to AR technologies can lead to healthy brain development as it allows children to use their imagination, view the world from the perspective of others, engage in topics of interest, and practice decision-making [12]. Ultimately, the following are implications for practice and future AR development:

- For users who cannot physically manipulate objects, AR can serve as a medium to bridge the gap between visually observing tasks (e.g. stacking blocks, placing puzzle pieces) and independent engagement through use of this technology.
- AR provides opportunities for development, play, growth, education, and leisure participation for individuals of all physical abilities.
- Individuals with physical impairments need to be included the development of AR-based applications and future AR-related research studies to ensure equal opportunity to access and participation.
- OTs perform activity analysis to assess physical, visual, cognitive, and psychological barriers to AR use to make appropriate and functional AT recommendations.
- Use of iOS touch accommodations, alternative access tools, and device positioning equipment creates opportunities for individuals with various motor profiles to access AR applications.

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