Using Mobile Augmented Reality to Improve Attention in Adults with Autism Spectrum Disorder

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Abstract
Adults on the autism spectrum commonly experience impairments in attention management that hinder many other cognitive functions necessary to appreciate relationships between sensory stimuli. As autistic individuals generally identify as visual learners, the effective use of visual aids can be critical in developing life skills. In this brief paper, we propose a Mobile Augmented Reality for Attention (MARA) application which addresses a lack of supportive and simple cost-effective solutions for autistic adults to train attention management skills. We present the proposed design, configuration and implementation. Lastly, we discuss future directions for research.

Author Keywords
Assistive technology; autism; attention; augmented reality; mobile applications.

CSS Concepts
• **Human-centered computing~Human computer interaction (HCI)**; Interaction paradigms~Mixed / augmented reality

Type	Definition
Selective	Ability to focus on a single task in the presence of distractions [15]
Sustained	Ability to remain focused for an extended period of time [15]
Spatial	Ability to distribute and reallocate focus across spaces [1]

Table 1: Three types of attention

Introduction

Autism Spectrum Disorder (ASD) is a pervasive neurodevelopmental disorder characterized by early-onset impairments in social communication, restricted or repetitive behavior [2] and attention management [32]. This has a long-term effect in adulthood in a large number of population [7,11] (e.g. 1% of the total population in the UK in 2010 [8]). Studies have shown that attention management is critical to the performance of other cognitive functions (e.g., decision-making, memory, problem solving [16]). Relationships between different types of attention (see Table 1) and sensory-processing abilities [11,25] have also been demonstrated. For instance, over-arousal to sensory information often occurs with over-selective attention, and is commonly exhibited in ASD [13]. This, in turn, is closely related to subsequent displacement behaviors in response to moderate arousal levels (e.g. hand-flapping, hyper-focused concentration on a single detail) [25].

Attention function impairments imply individuals with ASD may not perceive and integrate complex stimuli [14]; therefore, individuals may not be able to appreciate relationships between them. This disability has been shown to hinder many aspects of life for adults impacted by it (e.g., social communication, learning). For instance, few autistic adults develop and maintain the necessary skills to reach successful independent living [39].

Autistic individuals excel at visual search compared to neurotypical individuals and are most effective at processing visual stimuli compared to other sensory stimuli [20,28]. Given this, interventions have been developed on this basis, using either real objects, photographs, words, line drawings, or dynamic stimuli to help ameliorate social and behavioral impairments [28,36]. Technology, such as hand-held devices, has often been exploited, playing a key role in addressing ASD-related challenges [3]. Amongst other technological intervention strategies, augmented reality (AR) has been shown to be effective and more engaging given the unique way in which combinations of different types of visual representations are assimilated and understood more easily than non-visual cues [3,6,23]. This can also enhance real-world interactions by facilitating exposure to complex and dynamic stimuli through controlled virtual environments. AR on mobile devices can allow for cost-effective evaluation of symptomatic behaviors [16,33]. This explains its growing popularity for therapeutic and supportive uses.

Increasing efforts are being devoted to non-institutional rehabilitation support for autistic adults to develop adaptive skills to facilitate a sense of independence [17,23]. However, the presence of external barriers (e.g., inadequate access to technology, clinical support, and finances) and internal limitations, such as distraction and frustration autistic adults are susceptible to facing [21], restrict the use of assistive technology as an effective rehabilitative tool. The aim of this paper is to propose a system that is easy to use and inexpensive for autistic adults to improve attention management skills by interacting with real-world objects. The evolving capabilities of AR to merge reality with virtual elements in meaningful ways motivates us to explore the potential for its usage in developing novel interventions.

The key contribution of this work is a novel and simple design of a mobile AR attention training system as a cost-effective self-help intervention to support adults on the autism spectrum to train attention management. This builds on our literature review on existing studies on the feasibility of AR as a support tool for ASD. Next, we describe the design strategy and implementation of our proposed AR application. Finally, we discuss directions for future work**.**

Related Work

Different AR functions have been used to enhance interventions for people with ASD in a variety of ways. For instance, visual cues are used to teach social skills [24,26,30]. Gamification is used to elicit pretend play [4,37], mapping technology is used to train facial recognition [29,38], and trigger-based modeling is used for education purposes to teach vocabulary [27] and reading [18]. AR-based intervention differentiates itself from traditional interventions in its ability to bridge the gap between physical and virtual worlds[26]. Also, Bai et al. [4] highlighted higher engagement in AR intervention in comparison with non-AR.

Most research has focused on childhood interventions in improving ASD-inflicted attention management. For instance, smart-glasses were used to provide visual cues in the form of arrows to guide a child's gaze to a facilitator's face, which was overlaid with a virtual mask to further attract attention. This resulted in decreases in measures of inattention, as well as hyperactivity and impulsivity, 48 hours after the intervention [40]. Also, mobile AR has been used to increase the effectiveness of such interventions given its engaging and cost-effective way where focus can be controlled [14,15]. An example is MOSOCO [14] to help school children engage in sustained eye-contact and conversation by augmenting social situations with visual supports in the form of suggestions (e.g., "look at your partner's eyes").

Technological interventions deployed on mobile devices (i.e., smartphones, tablet PCs) reduce external barriers of accessibility and allow for the technology to be used in a variety of real-life situational contexts [9,10]. In a mobile AR application, teachers created a database of tagged images of objects for autistic children, who then used an object identification system in a school setting to identify them according to superimposed text and audio cues [15]. In addition to requiring minimal support while using the application, the children demonstrated a 45% increase in sustained attention during task completion [15].

Despite compelling evidence for the use of AR as a supportive tool for childhood ASD interventions, there remains a lack of empirical evidence studying interventions for adults. Therefore, this paper aims to build a mobile AR-based self-help intervention which is more engaging and cost effective in addressing the barriers faced by the underserved population of autistic adults. Furthermore, it examines the usefulness of AR interventions in situational environments for adults outside lab and classroom settings. Given the potential of mobile AR applications to support individuals with ASD in real-world situations, we propose a Mobile Augmented Reality for Attention (MARA) tool. MARA uses AR technology as a means to improve attention in adults with ASD through simple interactive visual activities.

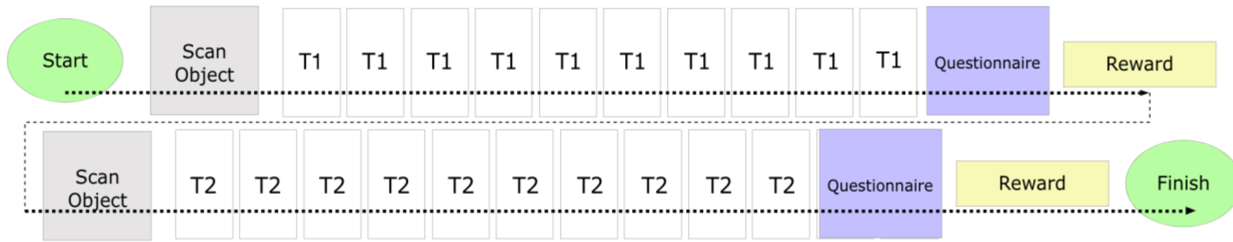

Figure 1: Proposed flowchart of the MARA therapy tool encountered by users once they have already completed the login requirements.

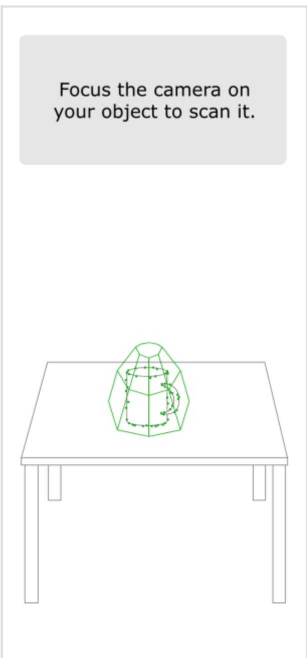

Figure 2: An illustration of the concept for selecting and scanning target object (e.g., coffee mug).

In the next section, we describe the design process of MARA, starting from our preliminary interviews for its conceptualization to the interface design. Also, we briefly discuss an experiment to test the efficacy of implementing the system as a therapy tool for attention impairments in adults with ASD.

Proposed Design

To obtain insight into how to conceptualize the MARA system, we conducted preliminary semi-structured interviews. Four healthy adults with ASD participated in the interviews (aged: 25-50 years, 4 males). Participants highlighted the importance of keeping features as simple as possible given that many features in mobile applications are usually distracting and not easy to use. Also, P2 preferred not to seek "outside help" (e.g., therapists, institutions) to deal with his behaviors and was more interested in self-help methods. P3 reported on being prone to getting stuck in intrusive patterns of behavior and experiencing difficulties in stepping outside his own perception of reality. Lastly, all participants pointed out the lack of mobile applications suitable for helping autistic adults in any context (e.g., social, cognitive).

This has led to the first objective of developing MARA which is to determine preexisting therapies that help autistic individuals form new attention management behavior. One such method involves a blocking procedure, which has been evidenced to aid autistic children in acquiring the ability to discriminate between colors or numbers [31,42]. This procedure requires repeatedly differentiating between cards with different colors or digits with the aim of training the ability to readjust focus and discriminate between them. For instance, one study placed numbered cards in random locations on a table over ten trials and required children to match the correct numbered card to a target [31]. Several interventions also involved the use of prompts and rewards and found this elicited positive emotions and motivation afterwards [15,31]. The concept of MARA is modeled after these methods and involves integrating virtual stimuli with physical objects, prompting the user with repetitive tasks, and motivating them with rewards. Given these concepts, several interfaces were iteratively designed. With each iteration, tasks were also developed in an attempt to understand whether someone with attention deficits could intuitively use the interface and how repeatedly completing the activities could be used to alleviate these deficits.

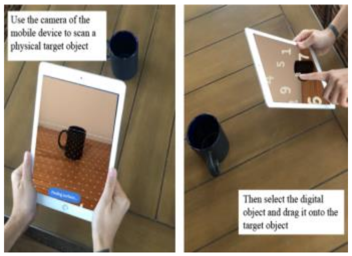

Figure 3: Testing the MARA interface using a coffee mug as the target object.

Figure 4: Performing a trial with the easy interface beginning with a. Target object scan; b. AR objects view; c. Object selection; d. Dragging the AR objects to target object; e. AR objects rearrange and tasks b – d are repeated.

Lastly, we determined how goal-achievement would be addressed. There is evidence that reward achievement increases neural activity in regions associated with motivation and performance monitoring in autistic adults [35]. Users would therefore receive a reward compensation for using MARA (e.g. scores in [12]). Each time a session of ten trials and a post-task survey is completed, the reward feedback is displayed (see Figure 1). This amount is contingent on their performance (i.e., higher performance elicits a greater reward).

Architecture

The application interface is based on the Unity3D game engine and Vuforia, a mobile AR development kit that enables computer vision functionality on smartphone operating systems. The Vuforia prefabricated components used include the AR camera and ImageTarget for object tracking.

Implementation

Following informed consent, first-time users enter an activation code to log in and are prompted to fill out a multiple-choice demographic survey with questions regarding age, gender, type of ASD, age of diagnoses, other diagnosed disorders, history of misdiagnoses as well as a self-report sensory profile survey based off questions from the AASP and Autism-Spectrum Quotient [5]. Instructional videos on how to properly scan objects and use MARA are provided to the user along with a training session where they must successfully scan an object and complete one trial from each of the two sessions to demonstrate their understanding of the procedure. Results from this session are not recorded.

The application uses superimposition-based AR to directly overlay digital content onto a physical object using a smartphone. Figure 1 shows the flowchart of the system. Users encounter two sessions with ten sessions each. Each session begins with the user selecting an object in their surroundings they want to focus on (Figure 2). While the object itself does not need to be recognized, as it merely serves as a target, users receive positive feedback when different objects are scanned at the beginning of each session to motivate them to interact more with their environment. During the sessions, the view of the environment is partially replaced with an augmented view with virtual stimuli (Figure 3, 4). After performing ten drag-and-drop tasks from the easy scenario, the user completes a short survey rating their levels of anxiety, motivation, and distraction on a visual analog scale. A rewards page displaying the user’s total earnings appears following the self-assessment. The user then completes the next session (i.e., the difficult scenario) which is also followed by a questionnaire and earnings page.

Individuals with ASD are susceptible to extreme responses resulting from hyper-reactivity to sensory input [40], making it important to maintain a simple interaction model requiring minimal attention demand [6,15]. Furthermore, Biocca et al. [6] found mobile AR using visual cues provides greater decreases in cognitive load compared to other commonly used attentional techniques (e.g., highlighting). Taking this into consideration, we randomly selected three basic three-dimensional (3D) shapes to use during the easy scenario (see Figure 4). In the difficult scenario, nine virtual digits surround the target object (see Figure 5). During each session, a text box displayed at the top of the screen prompts users to drag and drop a specific

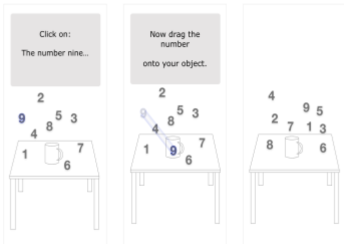

Figure 5: Step-by-step mobile interface concept for the 'difficult' condition

digital object (i.e., shape or number) onto the target object. Once the user successfully does so, the game rearranges the virtual objects for the following task. This is repeated ten times for each session. To avoid discriminating against those who may also suffer from other dysfunctions, such as color-blindness or dexterity impairments, designs with an overabundance of colorful stimuli, as well as stimuli that moved around the screen were discarded.

User privacy and sensitive personal information gathered from surveys are taken seriously, therefore only limited access to encrypted data will be available to researchers and clinicians. Anonymous versions of quantitative and qualitative data can be accessed remotely through a secure, cloud-based database.

Discussion and Future Work

To address the external and internal barriers facing interventions for autistic adults, this paper has proposed a cost-effective self-help intervention using mobile AR. This demonstrates the ability for simple novel technologies to be used as effective therapy tools. It is also worth noting that MARA allows autistic adults to perform tasks independently, which supports a sense of autonomy critical to their integration into employment environments and social communities.

Key limitations of this short paper should be noted. First, while the design of MARA uses Vuforia as an AR development kit, Vuforia faces instabilities in tracking and stimuli recognition depending on environmental factors [41]. A possible solution involves testing the feasibility of MARA using Vuforia and addressing potential instability issues with alternative AR development or 3D mapping frameworks [22,34].

Second, in order to enhance our understanding of the benefits of using MARA to train attention abilities, there is a need to involve experts on ASD to iteratively evaluate the system with studies involving participants with different ASD types. Further research is needed to discern how cognitive and physical abilities differ between high functioning adults and adults at the lower end of the spectrum in order to determine specific interventions appropriate for each type.

Lastly, several disorders that are highly comorbid with ASD share similarities in attention-related traits. For instance, approximately 40% of adults with ASD are also diagnosed with ADHD [19]. The presence of such confounding effects warrants further investigation on precise characteristics of attention. From there, we could explore additional interactive features (e.g. sound cues, haptic feedback), the integration of multimodal interactivity, as well as appropriate alterations to the proposed design. Addressing these limitations would help us identify more interesting ways to develop the application to make better use of AR to increase the user's interaction with their environment. A potential design, for instance, could incorporate the shape of the scanned object into the selection of virtual objects.

While the aim of the current paper was to identify the gaps in novel cost-effective interventions for adults with ASD, and to provide the first steps toward designing one, we expect to extend our preliminary research towards rigorous studies in which we develop and test a sustainable intervention solution to support a wider population of autistic adult and other neurodiverse groups, who struggle with attention management.

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