Puzzle Walk: A Gamified Mobile App to Increase Physical Activity in Adults with Autism Spectrum Disorder

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***Abstract*— Research shows that adults with Autism Spectrum Disorder (ASD) are less physically active than those without ASD. Persuasive augmented reality smartphone apps may be an effective intervention to target this health disparity. A gamified mobile app, Puzzle Walk was developed to elevate physical activity (PA) engagement in the target population following an iterative user-centered design process, including a literature review, identification of target behaviors, needs analysis, health behavior theory evaluation, and prototype design. We found that walking is the most common form of PA in the target users and they have an affinity to using technology devices. These insights led us to design the Puzzle Walk app that incorporates behavior change techniques (BCTs) (e.g., user instruction, self-monitoring, visual rewards, feedback on performance, and goal-setting). We describe the emerged design that includes animated gamification and visualized user interfaces. The usability assessment plan is discussed as future work.**

Keywords—physical activity; autism spectrum disorder; behavior change techniques; gamification; augmented reality

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a lifelong neurodevelopmental disorder that is characterized by deficits in social interaction and unusual patterns of restricted, repetitive behavior [1]. Although the benefits of carrying out regular physical activity (PA) on preventing secondary chronic diseases, including cardiovascular disease, obesity, and diabetes have been clearly confirmed [2], individuals with ASD do not meet PA recommendations [3]. Eaves and Ho reported in a survey study that adults with ASD engaged in moderate to vigorous PA only once per week and spent about 13 hours per day sitting [4]. This extreme level of inactivity may contribute to the high incidence of co-occurring hypoactive diseases observed in adults with ASD such as obesity, type II diabetes, hyperlipidemia, and hypertension [5].

Mobile apps using smartphones and tablets present a time- and cost-effective, innovative, and accessible way to increase PA in the general population [6]. Over the last decade, interactive technologies, including mobile apps, personal computers, virtual and augmented reality, and robotics for individuals with ASD have been remarkably advanced. Although the evidence supporting the efficacy of using mobile apps in adults with ASD is lacking [7], mobile technologies have proven beneficial in facilitating self-monitoring of PA and reducing sedentary behavior in the general population of healthy and obese/overweight adults, especially when compared to traditional interventions [8]–[11]. Above all, many individuals with ASD are visual learners and tend to be more comfortable in interaction with the predictable and persistent interface of mobile technologies [12]. Consequently, the gamified app-based interventions are likely to be an effective tool to prompt adults with ASD into PA engagement. Although gamified PA and fitness apps have become popular in the consumer markets, the scarcity of in-depth behavioral theory evaluation of gamified PA apps impedes our understanding of the impact of this approach in health behavior change [13]. Also, behavior change techniques (BCTs) have been extensively used in health behavior change studies, but a limited number of BCTs are applied in contemporary PA mobile apps [14].

We designed and developed a BCTs-based, gamified, PA-promoting mobile app called Puzzle Walk [14]. The present paper describes the iterative user-centered design process, including a literature review, identification of target behaviors, needs analysis, health behavior theory evaluation, and prototype design. We employed the modified version of Integrate, Design, Assess, and Share (IDEAS) framework, which provides a step-by-step guideline for developing and evaluating digital interventions [15]. The purposes of the present study are to: (1)

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investigate perspectives toward PA and technology device use in adults with ASD, (2) describe the iterative user-centered design process of Puzzle Walk that incorporates PA into gamified puzzle-solving activities using augmented reality (AR) technique, and (3) discuss future directions for usability assessment, including technical effectiveness, efficiency, and user satisfaction.

II. METHODS

The iterative user-centered design process of the Puzzle Walk mobile app followed the modified IDEAS framework: 1) Empathize with target users; 2) Conduct a needs analysis and specify target behaviors; 3) Ground the app in behavioral theory; 4) Ideate implementation strategies; and 5) Prototype potential products [15]. Each phase was sequentially conducted, and the findings were used to design the Puzzle Walk prototypes. Despite a growing number of consumer health-related mobile apps, there have been a limited number of studies that provide a clear process of the app design, development, and practice guidelines [16]. Thus, we aimed to describe an insightful and progressive user-centered app design process that would provide a referable guideline to PA mobile intervention developers and investigators.

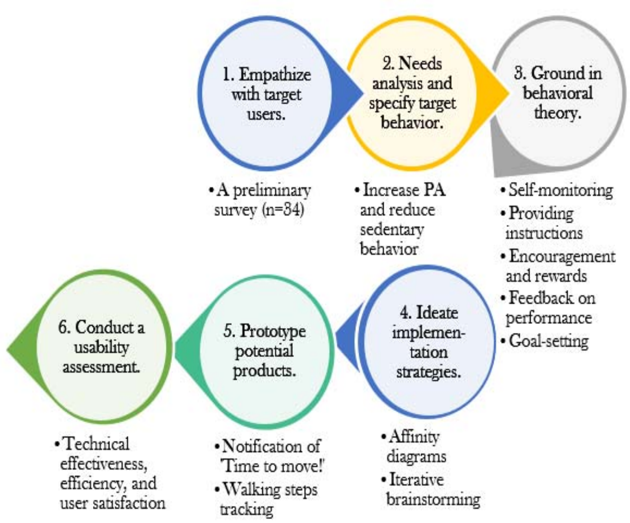

Fig. 1. Iterative development process of Puzzle Walk based on the modified version of IDEAS framework [15]

A 20-item online questionnaire was developed on the basis of the International Physical Activity Questionnaire [17] and the questionnaire designed by Gay and colleagues [18] to investigate digital technology use among individuals with schizophrenia. To gain insight into how adults with ASD perceive PA and technology device use in their everyday lives, questions focused on demographics, main forms of PA participation, main forms of technology use, and perspectives toward PA and technology device (e.g., "On average, how many hours do you walk in a weekday?", "How important is PA for your health?", and "What you usually do with your mobile technology device such as smartphone, tablet, and laptop?"). The online survey link was posted on autism advocacy group sites in Facebook and Reddit. A total of 49 individuals with ASD voluntarily completed the survey and 34 (18 males, 16 females) met the inclusion criteria of (1) age > 18 years, (2) presence of an ASD diagnosed by a qualified medical professional, (3) ability to walk without an assistive device, and (4) capability to understand the purpose of a study and complete the survey without assistance.

III. RESULTS

A. Physical Activity Participation and Technology Use

Respondents indicated that their most frequent forms of PA participation were walking (74%) and cycling (29%). More than half of the respondents walked less than 2 hours on both weekdays and weekends. Sixty-three percent of respondents reported that engaging in PA made them feel better.

Sixty-five percent and 45% used their technology devices more than 4 hours on weekend days and week days, respectively. Technology devices were primarily used to play games and read news. Forty-one percent of the respondents reported using social media, with texting and calling being the most common activities for communication/interaction, during technology device use. More than half of the respondents reported positive feelings when they used technology devices, and 47% reported negative feelings when technology was not available due to reasons such as work, homework, or house chores. A considerable majority felt technology devices were important in their lives.

B. Ideation and Prototyping

Survey findings clarified our review of existing evidence regarding PA and an affinity for technology device use in adults with ASD [3], [12]. One of the key findings was that walking was the most common form of PA, but little time was actually spent walking. The World Health Organization recommends adults ages 18-64 years participate in 150 minutes of moderate

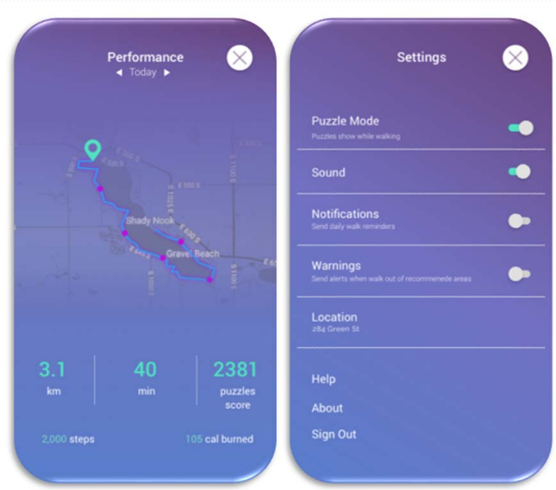

Fig. 2. Self-monitoring and feedback on performance BCTs applied in Puzzle Walk

to vigorous PA each week to receive health benefits [19]. Accordingly, we specified the target behaviors as: (1) increase PA engagement frequency and daily walking steps and (2) reduce time spent in sedentary behavior.

Our research team focused on increasing accessibility to PA by emphasizing walking and intrinsic motivation toward PA engagement as keys to sustaining an intervention effect [20]. As such, it was important to maximize user accessibility and intrinsic interests toward mobile apps using gamified visual feedback and AR technique. It was reasoned that this would promote meaningful changes in the target behaviors. A systematic review of studies on walking and cycling interventions indicated that intervention effectiveness was associated with the integration of self-monitoring with other self-regulatory BCTs [21]. As such, our research team employed the following BCTs for the Puzzle Walk app: (1) Prompt self-monitoring of behavior, (2) Instruction on how to perform the behavior, (3) Prompt rewards contingent on progress toward the behavior and successful outcomes, (4) Feedback on performance, and (5) Goal-setting (see Fig. 2). Considering possible discomfort in receiving sound or message feedback in individuals with ASD, a setting mode allows users to activate/deactivate sound for clue selection, daily goal reminder, and safety alerts (warnings). As part of BCTs Puzzle Walk provides users with daily and weekly progress information, including walking steps, distance, time spent for PA, burned calories, puzzle score, and visualized tracking.

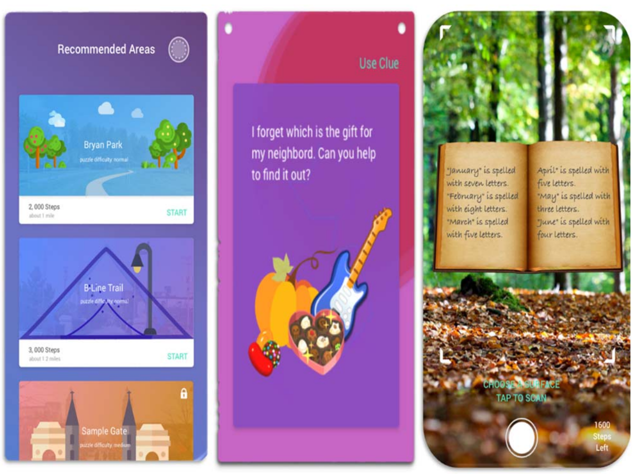

Fig. 3. Visualized user interfaces of Puzzle Walk

Following the overall assessment of user needs and target behaviors in adults with ASD, ideation was interchangeably conducted including, but not limited to gamification strategy, feedback mechanism, walking steps tracking, and analysis of user and context requirements. We concluded that visual support, safety, and walkable routes identification were pivotal factors, while also maintaining vigilance on potential risks such as traffic hazards or invasion of privacy, since the application would be mainly used in the outdoor community areas. We also acknowledged that minimizing context barriers such as surrounding visual or auditory distractions was critical considering the sensory sensitivities in the target population [1]. As a result, the final decision was made to create activity tasks that require users to solve puzzles and quizzes while engaging in PA to earn competitive rewards in and out of home environments. A central tenet of the app is to motivate users with ASD to 'sit less' and 'walk more' to improve health. Further, we concluded that mechanisms in solving puzzles and quizzes are grounded in continuing problem-solving and visual reasoning processes and which, in turn, can sustainably intrigue the target users with ASD to engage in PA. Therefore, the resulting Puzzle Walk incorporates the following interface design features: (1) minimal navigation elements, (2) visualized user instruction, and (3) gamified feedback using intriguing storylines and animated items based on AR technique (see Fig. 3). Designated community areas such as park trails or walking paths are automatically detected based on user's location information and users will be encouraged to walk along with a selected community route to secure safety and minimize environmental distractions. Visualized AR cues will be popped up on the device screen at a certain number of walking step and the program will require users to collect more cues to solve a given puzzle or quiz. The program mechanism is based on tracking walking steps rather than location changes. Accordingly, the negative effects of seasonal variation and severe weather conditions on PA are minimized by possibly engaging in indoor activities.

IV. Future Work

The initial version of the Puzzle Walk prototype was designed along with an iterative refinement process. Special efforts were made to simplify the user interfaces to minimize possible difficulties in the target users comprehending the purpose of the application and navigating the program. Accordingly, conversational narratives and visualized icons were emphasized utilizing BCTs, including self-monitoring, user instruction, visual rewards, feedback on performance, and goal-setting [14], [21]. Limitations include the small sample size and low reliability of the self-administered online survey. Future survey investigation should pay special attention to increasing the reliability of responses through constructing solid eligibility criteria, filtering process, and follow-up verification with the respondents. The usability assessment, including examination of technical effectiveness, efficiency and user satisfaction, is in progress based on the standardized evaluation method of the International Organization for Standardization 9241-11, which measures how users interact with a given product and provides an understanding of systematic usability evaluation [16]. The findings of a usability assessment will be critically used to refine visual work and functional interfaces to meet the unique needs in adults with ASD. A deployment study will be conducted in multiple community areas to examine the effectiveness of Puzzle Walk app in increasing PA and reducing sedentary behavior in the target population.

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