Augmented Reality on your smartphone to Improve living skills in subjects with Autistic Spectrum Disorder

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Abstract

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition that significantly impacts social interaction, communication, and adaptive behavior. One of the challenges for individuals with ASD is imitative and joint attention impairment, which can affect their ability to learn and perform daily activities. Video modeling (VM) has been shown to be an effective intervention for teaching various skills to individuals with ASD by leveraging observational learning. However, traditional VM often relies on therapist mediation, which limits the independence and autonomy of the learners. Recent advancements in technology, particularly in Augmentative Reality (AR), offer new possibilities for enhancing VM interventions.In this developmental and usability study, we evaluated the ShowMeHow app, which integrates AR to enable independent activation of VM on smartphones. The app was designed to improve the learning of daily living and social skills in individuals with ASD by providing video demonstrations in natural contexts. We tested a beta version of the app on a group of 20 adolescents with ASD level 2, focusing on its usability, effectiveness, and social validity. The study involved scenarios such as buying a ticket from an automatic machine and navigating a train station, aiming to replicate real-life situations.Our findings indicate that the Show Me How app is a promising tool for enhancing the learning experience of individuals with ASD. The app's user-friendly interface and AR features allowed users to independently access and follow video models, improving their ability to perform tasks in community settings. The study also assessed the app's usability through various metrics, including learnability, efficiency, efficacy, and satisfaction. Feedback from users and stakeholders, including therapists and parents, was collected to evaluate the app's social validity.Overall, this study highlights the potential of AR-enhanced VM to increase the autonomy and learning opportunities for individuals with ASD. By enabling self-directed learning in natural environments, the ShowMeHow app represents a significant step forward in the application of technology to support the developmental needs of individuals with ASD. Further research and development are warranted to refine the app and expand its application to a broader range of skills and user populations.

Keywords: Autism, Augmentative Reality, Dayly skills, ASD, Autism Spectrum Disorder

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1. Introduction

1.1. Background

Autism Spectrum Disorder is a complex neurodevelopmental condition characterized by a range of challenges in social interaction, communication, and repetitive behaviors (1; 35; 36). As the most part of neurodevelopmental disorder it can be present in comorbidity with other disorders, such as ADHD, Learning Disorders, and Intellectual Disabilities. A lot of people with autism shows impairment in adaptive behavior, that means the capability to use their skills in natural context such as school, peer relationships, workplace, or other community settings. Several authors showed the efficacy of Videomodeling (VM) in teaching these abilities in subjects with ASD (2).VM is a form of observational learning, in which desired behaviors are acquired by watching a videotape demonstration and then imitating ~~of~~ the target behavior of the model (3).VM capability to direct the attention of the observer on relevant stimuli for the action and on specific behavioural needs to be replicated, thiscould influence the learning process and it is intrinsically reinforcing characteristics, that could help to compensate stimulus over selectivity and imitative impairment due to social and joint attention challenges (4). Several studies underlined its efficacy to traindifferent skills in ASD, such as daily living skills (5), social skills (6, 7), employment skills (8), communication skills [9].Different kind of video modelingare described in literature (10): adult video modeling (AVM);peer videomodeling (PVM); selfvideo modeling (SVM) and video modeling with self-point of view (VMSPW), mixed models are used too. These models differ by the actor in the video. In AVM, who act the behavior is older thanthesubjects, in PVM they are the same age than thesubjectsin~~is~~ the model, in the SVM the subject self-act the video, same prompt are given and then removed fromthe tape. At the end VSPW in which the focus of the camerais set at eye~~s~~ level of the actor, so that it is show in the camerawhat he sees. Mixed models use different strategies in the same videos. For example, it startsas self-point of view and then shows the peer behave the action.In the last years new technologies such as Virtual Reality, Augmentative Reality and Artificial Intelligence took place in everyday life in amore accessible way. These technologies showed at different level usability in ASD treatment to improve social skills, everyday life skills and academic skills. As for example different studies suggest that immersive, interactive experiences have the potential to reach audiences on a deeper level than prior communications technologies (11; 12; 13). In Virtual Reality (VR), users engage with a story in an experiential way, interacting with their environment to uncover meaning. Battistoni et al. [14]explores augmented reality as a meta-user interface for interactive fitting rooms and its impact on the shopping experience. Researchers have already provided evidence that Augmentative Reality is useful for training typically developing children (15;16).AR learning activities have been proposed in many studies which demonstrate that an AR system not only provides students the basics anditis flexible and innovative (17), but it also positively increases the motivation to learn (18;19). AR attracts the attention of children with ASD and encourages them to maintain their focus on nonverbal social cues. Other experiments (20;21;22) support that claims also in special education. We projected and realizedShowMeHow App, an app for android and IOS based on basic principles of Augmentative reality. It can be used, easly by the user, to access to videomodeling in a natural context and began to improve their skills by itself. Our App could be used by subject to access to video modeling scanning of the object in natural context. After test the function of App on Android and IOS system, we will test the usability of the app in subject with ASD. So the aim of our study is to understand the affordability to integrate new technologies in Video modeling strategies to improve this technique further improve the learning opportunities of children, teenagers, and adults with autism.

1.2. Risk/Benefit Assessment

The subjects involved in the study will have access to the prototype of the app (App-Betha) on their phones for the duration of the experiment, to learn new abilities in their natural environment, The app will monitor their usage. No risk is associated to a correct use of the app. Immediate risks or long-term risks could be associated to a potential block of the app during and or after the experiment. This could be frustrating for the learners/subjects. Benefit Assessment is done with a Social Validity Questionnaire to main stakeholders: subjects with no cognitive impairments, parents of children and adolescents with ASD, Therapists, supervisors and clinical director. Potential risks for Subject will be measured with event recording and percent of occurrence.

2. Objective and Endpoints

The primary objective of the study is to determine the usability of the ShowMeHow app in helping individuals with Autism Spectrum Disorder (ASD) acquire new daily living and social skills. This app integrates Augmented Reality (AR) and video modeling to create an innovative learning tool. Usability, in this context, refers to the ability of users to operate the app efficiently and effectively without experiencing frustration. To achieve this objective, the study focuses on several key endpoints:

- Effectiveness: Assessing how well the app helps users learn and perform specific tasks.
- Affordability: Evaluating the cost-effectiveness and accessibility of the app for users.
- Usability: Measuring how easily users can navigate and use the app, including the frequency and nature of errors encountered.
- Learnability: Determining how quickly and efficiently users can become proficient in using the app.
- Social Validity*:* Gauging the acceptance and perceived usefulness of the app by users, caregivers, therapists, and other stakeholders

These endpoints are crucial for understanding the app's potential to improve the quality of life for individuals with ASD by enhancing their ability to perform everyday tasks independently(23). The study aims to provide a comprehensive evaluation of the ShowMeHow app, ensuring it meets the needs of its users and can be effectively integrated into various educational and therapeutic settings ..

3. Methods.

3.1. Study Design

According to ISO (1998), usability is characterised as the degree to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use (24, 25).Learnability is added to the usability model (26). The variables tested are:

- Learnability involves communicating how easy it is for users to understand, use and become proficient with the application: Learner friendliness will be measured by the number of errors made by students when using the application and by a questionnaire administered to the therapist. Accessibility, which improves accessibility for users with different levels of experience or ability, will be measured with a t-test for independent samples between groups two groups of subjects with ASD. One group will be trained to use the app, the second group will not be trained.
- Efficiency: refers to how well it performs its functions in a timely and resource-efficient manner. It will be tested through the user questionnaire to subjects and therapists.
- Efficacy: refers to the ability of the application to achieve the goal for which it was created. Efficacy will be tested with MANOVA test between three group. Two group will use the app (trained and not trained before) and one will use the video modeling activated by the therapist.
- Satisfaction: will be assessed by a questionnaire for subjects and a social validity questionnaire for therapists and stakeholders.

Two stages of pilot tests was used to assess the usability of the app.

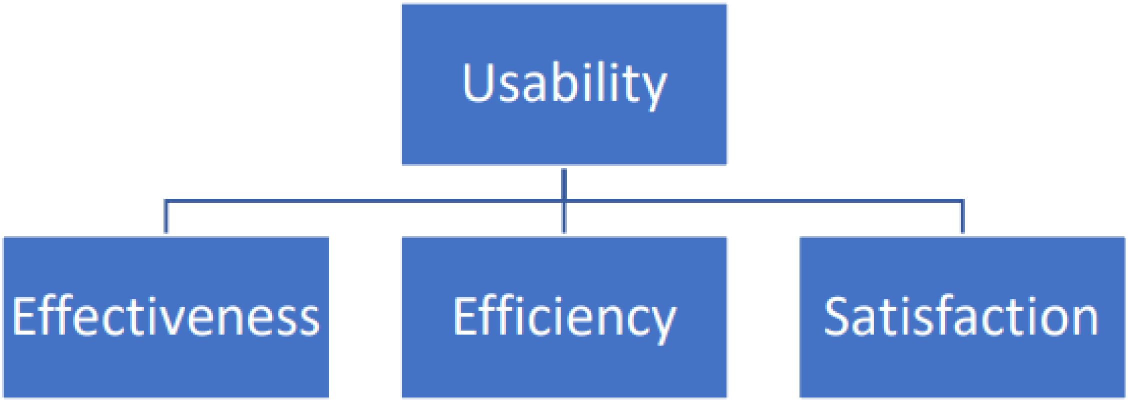

Figure 1: ISO Usability Model. From Park, J., &Zahabi, M. (2021, September). A novel approach for usability evaluation of mobile applications. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 65, No. 1, pp. 437-441). Sage CA: Los Angeles, CA: SAGE Publication

3.2. Study Population

The study sample will comprise 30 adolescents aged between 13 and 18 years, diagnosed with ASD Level 2. Recruitment will be conducted by the Italian Neurodevelopmental Disorders Foundation (FINDS). Autism diagnosis will be established through the use of Autistic Diagnostic Observation Schedule 2nd edition (ADOS 2).

Inclusion criteria require subjects to have an intellectual quotient between 75 and 85, which will be assessed using the Wechsler Intelligence Scale for Children IV ed. (WISC IV). In addition, their adaptive quotient should be moderately low (71 < QA < 75), as measured by the Vineland Adaptive Behavior Scale 2. Technical abbreviations will be explained upon first use. A specific inclusion criterion is the ability to follow traditional video modeling, demonstrated by a therapist or psychologist to enhance their skills.

3.3. Study Intervention: Description of the APP

An app based on Augementative Reality was developed to learn to users with Autism Spectrum Disoreds to use object in their real life.An app based on Augmented Reality has been developed to assist users with Autism Spectrum Disorders in learning to use objects in their daily life. The app, called ShowMeHow-App, has a simple interface, allowing for immediate use by the user. The app, called ShowMeHow-App, has a simple interface, allowing for immediate use by the user. It replicates a video recording on its icon, and upon opening, the camera is activated. When the camera detects an object that is already in the app's library, it is highlighted in green, and the user can click on it to start video modelling. When the camera detects an object that is already in the app's library, it is highlighted in green, and the user can click on it to start video modelling.The videomodeling show how this object could be used in the context where it is be scanned. Two modalities could be show with subtitle or without subtitle. In the setting of the app these chosen can be made: with or without subtitle; with or without audio; with or without vocal instruction.The application could benefit from the functionality to insert videos into the library or for the user to import their own videos. The application settings are accessible to the user by pressing and sliding on the right side after 5 seconds.

3.4. Study Assessment and Procedure

The sample was randomly divided into three groups based on gender using cluster sampling: Group 1 (G1), Group 2 (G2) and Group 3 (G3).

Scenario performed is to heat up a meal using the microwave and prepare a cup of coffee. The therapist will demonstrate to the user how to open the camera on their phone, position it towards the microwave until it turns green, and then click on it to access the virtual manual and instructions on how to operate it.The therapist may employ various prompts during this phase to instruct on how to align the object and access the video by clicking on the link. As a model, they will demonstrate how to use it, and then provide additional prompts as necessary until the individuals have acquired proficiency with the application.Acquisition is considered successful when the app is opened three times, and the user gains access to the video without any prompts, with a 100% success rate in three consecutive trials in both T1 and T2 conditions. The subjects of G2 and G3 did not receive any training in stage 1.

Using microwave task. The steps involved typical trails in using a microwave to heat a meal. For the first task, the process begins by retrieving a ready-made meal from the refrigerator, removing its packaging, and consulting the packaging for the appropriate cooking time. Next, the microwave settings are adjusted, the meal is placed inside, and the heating process is initiated by pressing the start button.

Making coffee with pods. The second task involves making coffee with pods. This starts by switching on the coffee machine and waiting for the orange light to switch off. Once the machine is ready, a coffee pod is placed into the machine, a cup is positioned underneath, and the start button is pressed. When the coffee reaches halfway up the cup, the button is pressed again to stop the process. Both sets of instructions provide clear, step-by-step guidance to efficiently complete these common kitchen tasks.

Table 1 summarize these activities.

Table 1
Task Table

	Task	Behavior
T1	Use a microwave to heat the meal	11) Retrieve a ready-made meal from the refrigerator. 2) Remove the packaging. 3) Consult the packaging for cooking time. 4) Adjust the microwave's settings and place the meal inside. 5) Initiate the heating process by pressing the start button.
T2	Make coffee with pods	1) Switch on the machine. 2) Wait for the orange light to switch off. 3) Open the pods and place it into the machine. 4) Position the cup under the machine. 5) Press the start button. 6) Press the button again once the coffee level reaches half way up the cup.

In the first stage, issues regarding functionality and user-friendliness shall be identified and resolved. In the second stage, groups G1, G2, and G3 will be tested in a train station environment. The subjects will be paired with their respective therapists who will instruct them on the required actions. Therapists shall not interact with the user or the application. G1 and G2 will be equipped with the phone and the SMH App, G3 can access to VM trough the therapists. Two scenario described in tab 2 will be assigned randomly among the subjects. After the acquisition of the first task. The experimenter will assign the second scenario to subjects.

Table 2
Task Table Scenario

	Task	Behavior
S1	Buy a ticket to automatic machine	1) Tap the 2) Select the language, 3) Enter the destination, 4) tap the ticket button, 5) choose to pay in cash, 6)insert coins, 7) then collect your ticket.
S2	Use your ticket to pass through the gates and proceed to the platform.	1) Please consult the platform display board. 2) Insert your ticket into the ticket validation machine. 3) Retrieve your validated ticket. 4) Pass through the ticket barriers. 5) Proceed to the designated platform.

The task outlines two scenarios for using an automatic ticket machine and navigating a train station. In the first scenario, the user needs to buy a ticket by tapping the screen, selecting the language, entering the destination, tapping the ticket button, choosing to pay in cash, inserting coins, and then collecting the ticket. In the second scenario, the user must use the ticket to pass through the gates and proceed to the platform by consulting the platform display board, inserting the ticket into the validation machine, retrieving the validated ticket, passing through the ticket barriers, and proceeding to the designated platform.

Interobserver Agreement (IOA). Interobserver Agreement (IOA) is a measure used to ensure objectivity and consistency in observations conducted by different observers. In this study, IOA was carried out among three therapists and one examiner. The IOA was calculated using the formula: (smaller score/larger score) * 100, based on the percentage of correct responses in the child's behavioral chain. The baseline IOA was 100% for all baseline measurements and ranged from 95% to 99% during training sessions, with an average of 97% during generalization sessions. This high level of agreement indicates reliable and consistent observations across different observers.

4. Stastistical Considerations

The data analyses were conducted using the statistical survey software SPSS 26.0 (2019). Significance was accepted at the 5% level ($\alpha < 0.05$).

To test user friendly was performed using the T-Test for independent samples between groups. The independent samples t-test is a statistical method used to determine whether there are any statistically significant differences between the means of two independent (unrelated) groups. Learnability will be assessed by comparing the mean error differences between G1 and G2 and the differences in mean acquisition time of the task between G1 and G2.

The group means were compared to evaluate efficacy in completing the task. The Multivariate Analysis of Variance (MANOVA) was used to compare G1, G2, and G3 on their acquisition time for the task in both the first and second scenarios.Post-hoc tests, such as Bonferroni or Tukey, may be used to ascertain which distinct groups exhibit differences from one another.

Qualitative Analysis of the questionnaire will be taken to analyze efficiency and satisfaction.

4.1. Social validity.

To evaluate the social validity of the ShowMeHow app, we gathered feedback from multiple stakeholders, including individuals with ASD, their caregivers, therapists, and educators. This feedback focused on the perceived usefulness, acceptability, and practicality of the app in real-world contexts. Users and their caregivers reported that the app's ability to provide immediate, context-specific video modeling was highly beneficial, particularly in promoting independence and reducing the need for constant supervision. Therapists noted that the app complemented traditional therapeutic interventions by allowing users to practice skills outside of structured therapy sessions, thereby reinforcing learning and generalization of skills. Educators highlighted the app's potential as a supplementary tool in classroom settings, enabling students with ASD to engage in learning activities more autonomously. Overall, stakeholders expressed high satisfaction with the app's usability, noting its intuitive design and the effectiveness of its AR features in capturing and maintaining user attention. The positive reception underscores the app's potential to improve the quality of life for individuals with ASD by enhancing their ability to perform daily tasks independently and confidently. Moreover, the integration of AR in video modeling was seen as a significant advancement, making the learning process more engaging and aligned with the technological interests of the current generation. These findings suggest that the ShowMeHow app not only meets the immediate learning needs of its users but also holds promise for broader applications in various educational and therapeutic settings. Future iterations of the app should continue to incorporate user feedback to refine its features and expand its usability to a wider range of skills and user demographics."

5. Considerations.

One of the primary challenges in ASD is to generalize learning to contexts different from the one where the training was conducted(23).VM is one of the most researched teaching methodologies for the education and treatment of Autism Spectrum Disorder (ASD). Its characteristics could respond to the difficulties showed by more ASD with cognitive and adaptive impairment (2,4).

In terms of literacy, the use of virtual models has demonstrated high levels of effectiveness among medium-tech assistive technologies used for Autism Spectrum Disorder (ASD) (27), and therefore is recognised as a best practice for ASD teaching (28) The advantages of Virtual Models (VM) can be summarized as follows: 1) Enhancing learning by presenting a variety of examples and settings, aiding in the maintenance and generalization of acquired behaviors; 2) Exerting greater control over the modeling procedure; 3) Facilitating the repetition of the same model(s) and enabling the reuse of videotapes for individualized learning (4).VM is based on a specific type of learning, known as imitative learning according to Bandura (29). However, several authors noted a significant impairment in imitation skills in individuals with ASD across abilities and contexts. This impairment appears to be linked more closely to their deficits in social and joint attention than their intellectual abilities (30,31).Although individuals with autism may face challenges imitating peers in certain contexts, they can be effectively supported in learning daily life and social skills through the use of videomodeling. However, most literature supporting the efficacy of videomodeling indicates that it is most effective when used under the guidance of an intervention therapist, and underline the importance to improve independency in their life (32).

In recent years, teaching techniques based on the use of new technologies (such as Virtual Reality and Augmentative Reality) have been proving effective for instructing daily life skills and social skills (33, 34). They have successfully addressed a teaching challenge in hazardous environments (35). However, one of the challenges, particularly for techniques involving virtual reality, is promoting independence and generalization (36).

In our study, we aim to evaluate the functionality of an augmented reality app designed for autistic individuals with similar cognitive impairments. The app can be used with or without minimal prompts from a therapist in a natural setting, aiming to enhance generalization of learning and improve self-determination.

Our application can enhance specific skills through video modeling while also promoting self-learning. Following training with the application, the user can utilize it in their setting without the need for assistance (subject to its functional capabilities) to access all necessary information relevant to the object's usage, thereby reinforcing their proficiency in its use.TheShowMeHow tool, even if tested on ASD level 2, could be utilised by all individuals with ASD without any cognitive impairment.

*Limitations.*While the study provides promising results, there are several limitations that should be addressed. The study's sample size is relatively small, with participants limited to adolescents with ASD level 2. Future tests should expand the sample size to include a more diverse group of participants, encompassing different age groups and varying levels of ASD. This will help generalize the findings and enhance the app's applicability. Onother limitation is that the study primarily focuses on immediate usability and short-term effectiveness. It is crucial to conduct longitudinal studies to assess the long-term impact of the app on users' independence and skill retention. This will provide insights into the sustained benefits and any potential areas for improvement over time. Moreover while stakeholders feedback is considered, the development process could benefit from more iterative involvement. Implementing a more iterative development process, where feedback from users, parents, and therapists is continuously integrated, will refine and enhance the app. This approach ensures that the app evolves in response to user needs and preferences. At the end it needs to ensure the app is accessible across various devices and technical environments.

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