Ergonomic Challenges and Benefits of Enhanced Cultural Application with Augmented Reality for People with Autistic Spectrum Disorder

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***Abstract*—Autism is a neurodevelopmental trouble which affects 1 child per 100 in the world. Known symptoms make museum exhibits difficult to access. The use of Augmented Reality (AR) (covering real environment with digital objects) by this population is growing rapidly but remains poorly documented, especially in the context of museum visits. AR used in this context often involves the use of a tablet and not a headset, as in the present experiment. 40 recruited participants will visit museums using augmented reality devices. The benefits of such a device will be assessed using an ergonomic evaluation grid. Psychometric tests will also be proposed to assess the cognitive cost of the protocol for the participants, alongside with observation and interviews. In this way, data about acceptability of the equipment, suitability of the software for our participants, relevance of the course and content of the application and about the behaviour induced by the AR device will be collected. This project aims to assess to which extent augmented reality can be implemented in the realization of a tour museum route by a participant with an autism spectrum disorder. This research will shed light on the advantages of using an augmented reality headset compared with a tablet, which has already been widely documented. In addition, a comparison between traditional visits and visits based on augmented reality will truly highlight the benefits of AR technology. Ergonomic criteria relevant for ASD participants not yet explored in the literature will also be investigated.**

Keywords-autism; augmented reality; museum; inclusive culture; ergonomic.

I. INTRODUCTION

This first section will give an overview of the existing litterature relative to our work about Autism Spectrum Disorders, stakes of cultural inclusion and Augmented Reality Challenges.

A. Particularities of ASD and care

France has approximately 700,000 people with Autism Spectrum Disorders (ASD), including 100,000 children. As described in the Fifth Edition of Diagnostic Manual of Mental Disorders (DSM-5) and the Eleventh Edition of International Classification of Diseases (ICD-11), social interaction and communication deficits are key characteristics of autism. People with autism are a very heterogeneous group and it is difficult to list defining symptoms. Rapid progress in technology, especially in the area of robotics, offers tremendous possibilities for innovation in treatment for individuals with Autism Spectrum Disorders (ASD). Advances in recent years have enabled robots to fulfill a variety of human-like functions, as well as to aid with the goal of improving social skills of individuals with ASD. Autistic children typically have difficulties with social interactions and cooperation. So, they might be uncooperative because they have not learned the appropriate behaviour for different social situations. Or they might not be able to manage the strong or difficult emotions, like anger, frustration or anxiety.

B. Stakes of cultural inclusion

Museums are places of culture and knowledge open to all. Unfortunately, without sufficient adaptations, many people with disabilities can find it difficult to fully enjoy these places. This project proposes the discovery and inclusion of children, teenagers and adults with disabilities in artistic culture, through augmented reality. Our desire to promote inclusive culture is fully in line with the work of the Culture-Handicap national commission set up in 2001, which is working to adapt cultural environments, particularly through digital tools. As a result, the commission has highlighted the effectiveness of augmented reality, particularly for the deaf and hard-of-hearing (Ministry of Culture, 2021). It thus affirms the need to include people with disabilities in the world of culture. However, access to culture can present challenges for people with disabilities. It is therefore necessary to adapt the activities and media on offer to enable them to access, produce and understand cultural works. Digital tools are becoming increasingly popular, and meet the adaptation needs of autistic people. There are many advantages to adapting a museum exhibition for people with disabilities. It ensures that culture is accessible to all, including people with disabilities. Indeed, disability is a social reality that affects around 20% of the French population. In addition, the use of digital tools is becoming increasingly popular, and meets the needs of autistic people in particular.

C. Augmented reality challenges

Augmented Reality (AR) is defined as a covering of our real environment with digital and computer-generated objects. They consider it to be a conceptually and historically derivative of virtual reality where users are immersed in a virtual and computer-generated environment [1]. Unlike Virtual Reality (VR), where users are isolated from their familiar surroundings and have the impression that the objects around are computer-generated [1], AR systems are designed to give users the impression that virtual objects are superimposed on real ones: they perceive both the physical environment around them and digital elements presented on top of it [1].

However, previous researchers point out a number of limitations to augmented reality. Indeed, most augmented reality applications are coded by professionals, with very little reuse possible of previously produced code [2]. One of our aims is to open up the development of augmented reality applications to non-programming professionals, and to facilitate it with efficient methods for creating and maintaining augmented reality applications.

Focusing now on the use of AR in a museum, the Art++ project give a first example of AR integration in such an environment. It was shown by the authors that augmented reality-based tours in museums would enhance users' learning abilities [3]. Visits using augmented reality increased the time spent concentrating on paintings [3].

To still illustrate the case of augmented reality used in museums, authors use the "The Ara as it Was" AR tool, which applies to Italy's Ara Pacis Museum, to gather data on the impact of augmented reality on the experience and satisfaction of museum visitors [4]. The results highlight average and high levels of satisfaction, confirming the effectiveness and innovation of augmented reality in museums. Other dimensions, such as the information provided by the museum, the enhancement of cultural heritage, and the educational dimension seem to be the most important criteria for users. Conversely, socialization, entertainment and a sense of escape are perceived as less important.

Litterature also mention the Archeoguide project [5], which "provided users with personalized 3D information on missing artifacts and reconstructed parts of damaged Greek temple sites" [2], and the Lifeplus project [6], which offers an innovative 3D reconstruction of ancient frescoes. Through these projects, it was highlighted that users like to listen and look, but not be active while using the guide [2]. Consequently, the guide should offer story-like entities without requiring the user to do too much [2]. In addition, users were happy to have more visual information, especially the 3D elements [2], but this raises an ethical question concerning the copyright of works. It is therefore possible to involve artists in the design of these 3D elements [2]. Other tips included the need for the tool to provide real-time localization on a map and a navigation guide [2]. The authors also mentioned that AR can be new to inexperienced users, so a simple interface is needed.

Other limitations and precautions to the use of AR in museums have been noted in the literature. First of all, there could be a lack of knowledge about the impact of augmented reality used in museum visits on engagement and interactions with art [3]: indeed, presently there is little literature data on user interaction with art-related augmented reality applications. A few other limitations, centered mainly on the use of a tablet as an augmented reality medium for the authors' Art++ project, were mentioned: notably the tirability of holding the tablet and the constraint of having to direct one's gaze towards different sources of information. It was also difficult to know where to focus one's attention due to too much information sources. These difficulties can be overcome by using another type of display device.

Finally, on the subject of precautions, [2] point out the importance of adjusting the size of visual markers added by augmented reality (as it is difficult to find the right size so that these markers do not hide the works of art or take up too much space). Care must also be taken not to alter the works of art too much with superimposed elements. On the other hand, the augmented reality museum guide should ideally run on affordable, lightweight, easy-to-use and robust equipment. As for the museum guide, it should not distract users' attention, so that they can observe the works of art directly as much as possible.

D. Interests of an inclusive conception

Numerous studies [7] [8] show that the use of augmented reality can increase motivation, attention and concentration and other areas affected by ASD. AR enables interaction with the real world, making it easier to discover and understand real-life situations through digital content. Other studies highlight the contribution of augmented reality with autistic children in developing fine motor skills [9] and visual attention [10] [11]. What is more, AR can be easily adapted. It thus takes advantage of the marked attraction for visual stimuli by users with ASD. This makes it possible to use this sensory modality to convey relevant information for their benefit. It thus proves to be an effective teaching aid [12].

Some authors added elements of usability applied to autism, stating that the immersion offered by augmented reality increases user engagement and motivation, which is crucial for individuals with ASD who may have attention or sensory deficits that impact their desire to learn [13]. It is also worth noting the importance of habituation, as a headset habituation program has been shown to reduce the stress caused by wearing an augmented-reality headset.

Researchers attempted to explore the potential of new technologies, and more specifically augmented reality technologies in museum settings for people with ASD [14]. To this end, they developed a support based on these technologies to make a museum visit more accessible for people with autism. The results that emerged from the experiments linked to this visit showed that augmented reality enabled significant benefits and improvements in terms of autonomy and the ability to explore the museum for people with disorders or more specifically an autism spectrum disorder.

As for the authors of [15], they gave some examples of conduct and adaptations that may be necessary when using a virtual/augmented reality headset by an ASD audience in a museum. These include site-specific features (sufficient size, calls to interact, 360° angle view of works, special effects used sparingly, works easy to handle, plurality of media types, simplicity of language), content-related elements (easy-to-read information, high contrast, large font, system for reading written text, pictograms, colorful illustrations), as well as items relating to the use of the helmet (customization of brightness, several types of support possible, several types of locomotion mode, limiting the use of fine motor skills, customization of the environment, avoiding triggers for side effects of the headset).

In short, there are few references in the literature on the use of augmented reality in cultural environments for people with ASD. However, there are already a few clues as to how to develop an augmented reality tool for such a population. The rest of the paper is structured as follows. In Section II, we present the objective of the study alongside with our main and secondary hypotheses. Then, in Section III, we describe the material and methods of the study : it emphasises participants, protocol, tools and equipment used. Section IV is dedicated to discussion and we finally conclude and discuss future work directions in Section V.

II. Hypotheses

Now, objectives and main hypotheses will be introduced.

A. Objective of the study

This project will first study the degree of acceptability of augmented reality headsets by a public of children with ASD according to pre-established criteria. It will then focus on the ergonomic evaluation of an augmented reality application used by the very same population to enhance two visit itineraries of the *Musée de L'Ecole de Nancy*, making them comprehensible and adapted to the particularities of ASD children.

B. Main hypothesis

The research problem is as follows: To what extent can augmented reality be implemented in a museum exhibition to enhance comprehension for individuals with ASD?

C. Secondary hypotheses

- Sub-hypothesis 1: When the hardware, software and content presentation criteria scores are high, subject will perceive the application as being more recreational.
- Sub-hypothesis 2: When the hardware, software and content presentation criteria scores are high, subject will perceive the application as being more educational.
- Sub-hypothesis 3: For an ASD participant, completing an AR course results in a higher educational nature perception than during a conventional course.
- Sub-hypothesis 4: For a participant with ASD, an AR tour enables them to find their way around the museum better than during a conventional tour.

III. Material and Methods

Methods will be described here through participants, the global protocol, the tools, and the equipment used.

A. Participants

Regarding the participants, it is envisaged to recruit 30 children and adolescents with autism spectrum disorder and intellectual disabilities from the various establishments of the J.B. Thiéry association in Maxeville, France. These participants are aged between 8 and 16. Ten adults participants, also with an autistic spectrum disorder and aged between 18 and 35, will be recruited from the *GEM Autisme (Groupement d'Entraide Mutuelle Autisme)* in Nancy, France.

Non-inclusion criteria for the recruitment of our participants have been implemented. We have therefore decided not to include participants with autism comorbidities, such as the presence of another neurodevelopmental disorder, participants who are prone to epilepsy or who experience headaches when wearing the augmented reality headset.

B. Protocol

The first step of the research is the development of an augmented reality application that will be used during visits to the *Musée de l'Ecole de Nancy*. This application will be divided in two parts. One will be devoted to a themed floral tour, while the other will focus on a tour about the fauna. Once participants have been recruited according to the criteria set out above, an initial test of the application will be carried out with teachers and accompanying adults. In this way, adjustments may be made in anticipation of the experimentation with participants. Then, the benefits of using augmented reality in the context of a museum visit for an ASD public will be assessed during the experimental phase.

C. Tools

Now, the evaluation tools expected to be used in the research will be introduced. Some of these have been found in the literature, while others have been designed specifically for the study.

1) Ergonomic evaluation grid: The first tool that has been developed, which is also the focus of our experimentation, concerns the ergonomic evaluation of the augmented reality headset. After reviewing the literature, there was so far no exhaustive ergonomic evaluation grid established for such a device. In fact, only a few papers focusing on AR mentioned some of the relevant ergonomic criteria that should be assessed without drafting a holistic list. The grid lists the criteria already present in the literature alongside with added elements that are relevant to the object of study (augmented reality applied to a museum context) and to ASD participants (Table 1).

The grid is broken down into several dimensions: criteria relating to the hardware, the software, the behaviour of the participants, the presentation of the content of the application and visit as well as criteria relating to the secondary effects

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caused by wearing the headset and the cognitive cost of completing the visit.

The hardware ergonomic criteria focus on a number of important points relating to the headset use. For each participant, the perceived weight of the headset, temperature, tactile acceptance, battery life, balance of the back of the helmet, intuitive handling, adjustability, overall comfort, noise level and ease of use will be assessed. All this information will whether the equipment used is suitable for ASD participants or not.

Criteria relating to the software aspect will focus on the accessibility of the controls, hand tracking by the augmented reality headset, the fluidity of eye tracking, the degree of adaptation and the options offered to the user, the legibility of the route, the content of the activities and the relevance of the information presented. The educational and entertaining nature of the augmented reality application will also be evaluated. The assessment of these ergonomic criteria will bring out relevant modifications and adjustments to implement to the application in a user-centered approach.

The user's behaviour during the visit will also be observed. Notes will be taken about the user's mood, the interactions they initiate, their exploration of the space with their eyes and their ability to find their way around the space. This will bring out an overall view of the effects of the device on the participants conduct.

About the presentation of the content, care will be taken to ensure the simplicity of the interface and menus, the legibility and clarity of the images and the appropriate size of the text and images. Those pieces of information will be invaluable in assessing the accessibility of our application.

Finally, attention will be paid to any side effects associated with the use of the headset (such as nausea, dizziness, loss of balance, visual fatigue, headaches, etc.). The cognitive cost of completing the course will also be quantified using tests that will be presented further. Due to the potential tiredness of ASD people, it will be relevant to have an overview of the cognitive load induced by visiting the museum with the augmented reality device.

Most of these criteria will be assessed on the basis of observation and interviews. However, some of them will require the use of additional tools or the conduct of activities. In that way, to assess the educational nature of the application, it may be necessary to ask the participants to draw up a narrative diagram of the activities carried out, to put in order images in order to reconstruct the visit, to associate the images with the museum rooms visited or to take the reverse route of the visit and explain what has been seen. In the same way, the cognitive cost of the tour will be observed on the basis of psychometric tests: the comparison between the performance of short-term memory / inhibition at the beginning and at the end of the tour seems to be a good indicator of that cognitive load.

2) Inhibition assessment: To assess the cognitive cost induced by completing the augmented reality course, it is planned to evaluate inhibition performance. With this in mind,

TABLE I. ERGONOMIC ASSESSMENT GRID.

Hardware	
1. Weight	1: External battery plugged in
	2: Without external battery
2. Temperature	
3. Tactile acceptance	
4. Battery life	
5. Balance of the headset	1: With the base strap
	2: With the rear support
6. Intuitive handling	
7. Adjustability	
8. Overall comfort	
9. Noise level	1: With the fan plugged in
	2: Without the fan
10. Ease of use	
11. Portability	
Software	
12. Accessibility of controls	
13. Headset hands tracking	
14. Fluidity of eye tracking	
15. Degree of adaptation/options proposed to the user	1: For the headset OS
	2: For the application
16. Clarity of the route	1: Through the museum
	2: About points of interest
17. Activities	
18. Playfulness perceived by the user	
19. Educational nature of the application	
20. Relevance of the presented information	1: Audio information
	2: Visual information
Behaviour	
21. Thymia	1: Overall thymia
	2: Frustration
	3: Evolution of the mood
22. Interactions induced by the use of the headset	
23. Exploring space with the eyes	
24. Situate oneself in space	
Presentation	
25. Simplicity of interface and menus	
26. Image legibility and sharpness	1: At arm's length
	2: At a distance of 4 meters
27. Size of text and images	
Others	
28. Presence of side effects during use	
29. Cognitive cost of the visit	1: Short-term memory
	2: Inhibition

a Stroop effect test has been extracted from the literature which is based on a theme corresponding to one of the two thematic courses of the application (the wildlife theme). It allows us to rediscover the Stroop effect with boards based on animals known to the general public [16]. Its principle is to inhibit the quasi-automatic reading of an animal word-name in order to name the animal presented in an associated image.

The Stroop effect is preserved despite the change in medium type for the following reasons: The test offers a control board where the written word corresponds to the image of the animal, so the interference phenomenon does not occur. In addition, the second board displays a word that does not match the subsequent image (Figure 1). Finally, the words and images refer to animals that are well known to everyone. As a result, there is no risk of semantic complexity interfering with the smooth running of the test (as well as in the classic Stroop test with colours).

To be as faithful and close as possible to the original Stroop effect test, it is planned to run the control condition before the interfering condition.

Still to assess inhibition, but this time for the second course on the theme of flora, it is envisaged to adapt the Stroop effect

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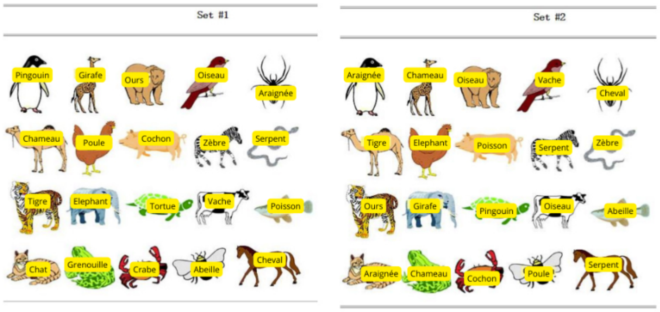

Figure 1. Stroop Effect Test based on animals [16].

that has just been presented [16] to the theme of the plants.

Based on the authors mode of presentation, the animal theme will be transposed to a plant theme by replacing the images and names of animals with fruits and vegetables: these will be familiar to the general public, easily recognizable and will not present any phonological complexity (fewer than 3 syllables) in order to preserve the purity of the test. The Stroop effect is preserved despite the change in the type of support because of the following reasons: The test proposes a control condition in which the written word corresponds to the image of the fruit or vegetable and therefore the interference phenomenon does not occur. In addition of that, the second condition displays a word that does not match the subsequent image: an interference occurs when the word is read before the plant is named (Figure 2). Finally, the words and images referring to fruits and vegetables are well known to everyone. As a result, there is no risk of semantic complexity interfering with the test (as in the original Stroop effect test with colours).

In order to be faithful and as close as possible to the original test, the control condition will be passed before the interfering condition. Furthermore, to be close to the material of [16], images with a similar graphic style will be used for our plates.

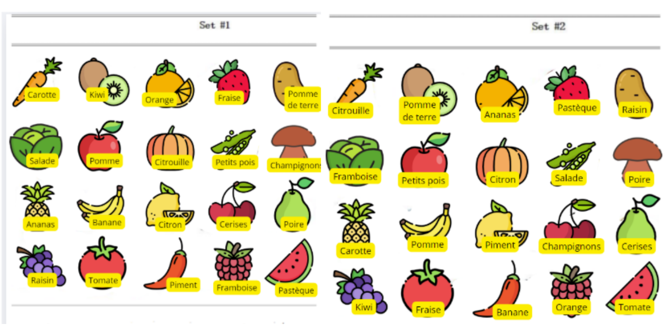

Figure 2. Stroop Effect Test based on plants (adapted from [16]).

3) Short-term memory: To complete the assessment of the cognitive cost of visiting the museum, a second dimension will be evaluated, namely short-term memory. To this end, a short-term memory test has been extracted from the literature called 'Animal Race' which is perfectly suited for the wildlife trail part of the application. Thereafter, this test has been adapted to the theme of flora for the second plant-based route.

For the first route (wildlife route), the participant is asked to name the order of arrival of animals in a race after the examiner has verbally given the order of arrival. The number of animals involved in the race varied from 2 to 7, enabling memory span to be measured.

The animal race test has been chosen because it has the advantage of not involving language to any great extent, and is therefore accessible to as many people as possible. That choice has also been made because of this test ability to isolate working memory. There are a number of reasons for this: first, the animals have short and simple names that do not require overly complex phonological processing. In addition, the animals used in the test are familiar to everyone and it is easy to associate them with images: there will therefore be no interference from semantic complexity during the assessment.

As for the flora trail, the animal race test has been adapted to a plant-based version. The subject will be asked to rank plants according to their development and highest growth.

Based on the reference article on the animal race, four criteria emerge for choosing the plants to be ranked: Firstly, the plants should have a short, simple name that does not require overly complex phonological processing (to avoid any form of phonologically induced overload). Ideally, they should be monosyllabic. Next, the word associated with the plant should be familiar to everyone as far as possible, and its semantic association easy. This is to avoid any bias due to the potentially complex meaning of the words. In addition, the plants must be linked to pictograms that are easily recognizable and presented in a common graphic style. Finally, 7 different plants had to be implemented in order to cover a memory span of 7 items as in the original test.

In addition to that, to respect the race principle, the plant presented first by the examiner will have the highest growth and so on in descending order. Also, each item in the plant race will be associated with an item in the baseline test, in a such way that the word presentation order will be identical to the original test.

Figure 3. Pictograms used for our adaptation of the animal race test entitled 'the plant race'.

D. Equipment

Regarding the equipment, it is planned to use Meta Quest 3 headsets of the Meta brand. To ensure a better balance between the front and back of the headset, an additional strap will be clipped to the device.

IV. Discussion

The use of Augmented Reality (AR) in museums is an emerging field that holds significant potential, especially for enhancing accessibility among populations with specific needs, such as individuals with Autism Spectrum Disorders (ASD).

Figure 4. Meta Quest 3 picture.

Most existing studies have utilized tablet-based AR technologies, which, despite their documented advantages, present certain ergonomic drawbacks. Tablets can induce user fatigue due to prolonged carrying and create divided attention between the screen and physical exhibits. In contrast, AR headsets have the potential to mitigate these limitations, offering a more immersive, hands-free experience that allows users to engage directly with artworks without the distraction of constantly shifting their gaze.

In exploring the implementation of AR headsets within museums, particular attention must be given to the ergonomic and ethical considerations. Ergonomic criteria, such as device weight, ease of handling, comfort, visual clarity, and adaptability to individual user needs, are crucial to ensure effective and comfortable usage, particularly for users with ASD, who may exhibit heightened sensory sensitivities or distinct interaction patterns. The evaluation grid developed in this study specifically targets these ergonomic criteria, providing comprehensive insights into the suitability of AR headsets for this audience.

From a methodological perspective, the current project addresses a notable gap by systematically comparing AR-guided museum tours using headsets with traditional museum visits. This approach allows for rigorous evaluation of AR's actual impact on visitor engagement, comprehension, and overall experience.

V. Conclusion and Future Work

This Work in Progress article gives us the opportunity to present our theoretical foundations. This was followed by a description of our methodology and the results we hoped to achieve. Finally, the discussion highlighted the implications that this research could have on the scientific landscape.

New evaluation tools developed specifically for this research, including ergonomic assessment grids, cognitive load evaluations through psychometric tests, and observational methods, provide robust mechanisms to measure not only usability but also educational and recreational outcomes. The evaluation of the relevance of these tools will be a part of our future work.

Ultimately, this project will deliver valuable empirical insights into the advantages and limitations of AR headset use within museum settings for individuals with ASD, highlighting critical ergonomic factors and the necessity of personalization. The results will contribute significantly to inclusive cultural practices. This will allow us to developp in the future practical guidelines for subsequent developments in accessible AR museum technologies.

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