


Usability and Accessibility of the ArtontheBrain™ Virtual Recreation Activity for Older Adults With Low Vision Due to Age-Related Macular Degeneration

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Abstract

Experiencing visual art can inspire, be an overall positive leisure activity, and has been linked to improved cognition, especially in older adults. Access to artwork in a museum environment can comprise a variety of barriers, including difficulties linked to its visual experience for persons that are visually impaired. The present study explored the barriers and facilitators experienced by 15 older adults (age 65 to 93) living with age-related macular degeneration when using an iPad to access ArtontheBrain™, a virtual art museum recreation experience created by members of this team. Using the Concurrent Think Aloud method, participants were asked to continuously comment on their experiences with the application while being audio/video recorded. Indeed, codes were determined by identifying frequently stated and emphasized ideas or behaviors of participants using the ArtontheBrain™ application. Transcripts underwent thematic analysis and indicated that the main access barriers were linked to control of the contrast, magnification, and the tactile interface on the tablet device. The learn and play activities as well as the text-to-speech feature were identified as facilitators for ArtontheBrain™ engagement. The present findings should also be considered in the larger context of application development, as this study provides insight pertaining to the needs of low vision individuals regarding usability and accessibility.

Keywords

low vision, accessibility, mobile application, aging, vision rehabilitation

Introduction

Much like in most high-income countries, in Canada, the older portion of the population is rapidly increasing,¹ mostly because of the pattern of demographic growth caused by the baby-boomers. With this population increase comes a rise in the number of older adults with age-related visual

impairment.² It is not surprising that acquired vision loss causes a decrease in the ability to complete activities that require vision, many of which are part of leisure, including access to performance theater, painting, or sculpture.³ The present study explores an alternative to accessing visual art via a web-based virtual museum, called ArtontheBrain™ (AotB), specifically designed to cognitively engage older

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Questions

What do we already know about this topic?

Participating in leisure activities that do not focus on performance has many benefits such as reducing social isolation and improved wellbeing.

How does your research contribute to the field?

To our knowledge, there is currently no available leisure application on the market that is accessible for older adults with low vision.

What are your research's implications towards theory, practice, or policy?

We aim to improve the current application by applying the present findings to create a more accessible and usable leisure application for low vision users, as well as exploring the potential health benefits of this adapted version.

adults. We focused on its accessibility for persons with a partial visual impairment and developed recommendations to further improve this type of interface for accessing visual artwork.

As someone is aging, declines in sensory function become more common and prevalent.⁴ Low vision (LV) is a decline of visual function that affects the ability to accomplish visual tasks, and that cannot be remedied with corrective or contact lenses, or other surgical or medical interventions (Corn and Koenig, 1996). LV is more prevalent with age, but it should not be considered part of the normal aging process. Indeed, LV is considered as pathological aging and can have detrimental effect on oneself physical and mental wellbeing. There are many age-related diseases that can affect an individual's eyesight and cause LV. The most common, age-related macular degeneration (AMD) is a degenerative disease of the macula (the central part of the retina) affecting the central visual field. AMD causes a loss of central vision, and individuals with AMD will encounter difficulties in their daily life such as recognizing people, walking down the stairs, and reading. AMD is characterized by photoreceptor cell loss in the macula in the dry form of AMD or cell damage due to the leaking of abnormal blood vessels in its wet form.⁵ Up to 25% of older adults aged 75 and older in Canada are affected by AMD. An individual with advanced AMD will mostly rely on peripheral vision and experience interference with usual activities of daily living, such as reading, driving or recognizing faces.⁶ Maculopathy (i.e., diseases of the macula) may have a detrimental effect on an individual's quality of life, both from a functional and a psychological perspective.⁷

Low vision affects a person's ability to engage in activities of daily living and can impair access to leisure and recreation activities,⁸ specifically for older adults.⁹ Even getting to and from the location where a social event is occurring becomes a challenge. Driving is not an option for most people with LV¹⁰ and finding accessible transportation to get to an activity can be difficult as well.¹¹ Having LV may be a barrier to participating in the recreational activity itself, because many

events are not adapted for people with LV. For example, appreciating visual art in a museum¹² or other activities older adults might engage in (e.g., golf, bowling, and playing cards) are less accessible for this population.

Several studies have indicated a close link between sensory and cognitive decline,¹³⁻¹⁶ whereby cognitive functioning appears more impaired in older adults with LV when compared to that of normally sighted older adults.¹⁷ Furthermore, visual impairment has been linked to an increased risk of Alzheimer's disease and an increase in the severity of the disease.¹⁸ More specifically, individuals with AMD or glaucoma participate in fewer cognitive activities than normally sighted controls, suggesting that individuals with these diseases may be at risk of future cognitive impairments.¹⁹ AMD has been linked to lower cognitive functioning¹⁷ and a higher risk of developing dementia, particularly Alzheimer's disease.²⁰ One study even proposed that glaucoma, an eye disease that affects peripheral vision,²¹ could be a manifestation of Alzheimer's neuropathology that does not affect memory.²²

Many hypotheses have been postulated to explain a link between sensory and cognitive decline. For example, the *information degradation hypothesis* states that the degradation of the perceptual inputs (i.e., sensory decline) may affect higher-level cognitive processes.²³ The *social-mediated hypothesis*, proposes that engaging in social activities can preserve or promote cognition.²⁴ As elaborated above, for people with LV, engaging in social activities may be more difficult. It can therefore be theorized that a reduction in social engagement and participation in social activities may have a negative impact on the cognitive functioning of older adults with LV and further increase their risk of future dementia. This hypothesis consolidates the importance of leisure and recreation activities, as well as therapeutic recreation interventions for older adults with LV.

The main intervention to improve functional vision for persons with LV is LV rehabilitation, where individuals

acquire strategies and tools to be able to complete their desired tasks.²⁵ For example, clients undergoing LV rehabilitation may learn how to use their peripheral retina for reading instead of using their compromised central macular vision.²⁶ Another way to overcome the challenges associated with LV is the use of assistive devices, for example, for magnification. Many mainstream devices can aid those with LV. For example, tablet computers can easily magnify with their intuitive pinch and spread commands²⁷ and can be useful for spot reading.²⁸ In the context of therapeutic recreation, the challenges of making virtual recreation activities accessible for older adults with LV were pointed out by Botner.²⁹ The author mentions the specific needs for high contrast, large font, and magnification options for this population when engaging in a virtual learning program. We therefore speculated that the accessibility features available in devices such as the iPad could be useful in the context of therapeutic recreation, specifically when viewing artwork. The beneficial effects of rehabilitation and adaptations for recreational activities for persons living with LV have previously been demonstrated by Mancil and Kuyk.³⁰ Their participants confirmed that recreation was an important part of their rehabilitation process, in part because of an increase of available time due to the onset of visual impairment, when many other activities (e.g., employment) were not possible anymore.

Technology offers multiple possible solutions to the problems created by LV as well as by dementia, by bringing leisure activities into the home of older adults that may otherwise not access such activities anymore. Loneliness is also a major issue in aging and has been shown to lead to cognitive decline³¹ as well as a reduced quality of life (QoL; Victor et al., 2000). Fortunately, there are ways to prevent or diminish loneliness as well as other aging-related issues. For example, taking part in leisure activities involving social interaction could be a way to contend with loneliness. A virtual learning program for isolated older adults in Québec has shown the potential to reduce social isolation.²⁹

Therefore, leveraging technology to increase accessibility to recreation has become specifically pertinent in the current era where social distancing prohibits many patrons from attending public leisure activities. There are many applications available for older adults, ranging from health apps to game apps³² to virtual learning.²⁹ Many of these applications focus on improving the cognitive health through what is referred to as “Brain Training.”³³ They provide a form of cognitive intervention that can be completed at home (e.g., on a laptop, tablet, or mobile phone) and have been advertised as tools to increase the cognitive capacity of the user.³⁴ However, their efficacy has been questioned and a systematic review indicated that little evidence of broad training transfer was available.³⁵ It has already been shown that leisure and recreation activities have many benefits, such as improving the quality of life and wellbeing of older adults.^{29,36} Creating more leisure applications, specifically for older adults, that are not performance focused as most brain

fitness technology products are, should further promote their ability to enjoy the benefits of leisure. Previous work has indicated that the quality of leisure time of individuals with LV or blindness depends on the type and availabilities of leisure activities.⁸ This highlights the importance of having leisure activities that are available and suitable for individuals with LV. Finally, research focusing on the usability of leisure applications for older individuals with sensory impairments is sparse, and its development could be a way to promote QoL and wellbeing among older adults.

In an attempt to bring leisure and recreation activities into the home via the use of technology, members of this team developed a web-based application (app) called *ArtontheBrain™*. AotB is a virtual art museum that makes visual art more accessible for older adults that are physically prohibited from going to a museum for any reason. AotB offers several activities to its users (e.g., puzzle games, informative texts, and storytelling) in relation to the selected artwork. This app also facilitates socializing, as it has online virtual community component where users can interact with each other sharing opinions and stories inspired by the artwork. Overall, the creation of the AotB application is aimed at promoting leisure activities, brain health and QoL. To date, research with AotB has relied on testing the application with normally sighted older adults, and preliminary data show that participants are able to independently navigate the application and report enjoying the AotB application.³⁷ The application has also been tested as a group intervention with older adults with mild to moderate dementia who are residing in long-term care and results show improved wellbeing in participants following access to the activity.³⁷

Current Study and Its Objectives

With the aim of being able to reach as many individuals as possible, the goal of the present project was to evaluate the accessibility of the visual components in the first iteration of the *ArtontheBrain™* application (1.0/beta version) through the perspective of visually impaired older adults. Consequently, the objective of this study was to identify the barriers and facilitators to accessibility and usability of the *Learn* and *Play* activity components of *ArtontheBrain™* from the perspective of older adults with LV due to AMD.

Method

Institutional Review Board approval for this study was obtained from the *Center for Interdisciplinary Research in Rehabilitation of Greater Montréal* (CRIR #1297-1117).

Participants

Eligible participants had to be 65 years or older with a diagnosis of age-related macular degeneration (dry or wet),

Table 1. Demographic Information.

ID	Age	Sex	Diagnosis	VA/OD	VA/OS	VA/OU	Near/VA
1	90	F	Wet AMD	6/15	6/180	6/180	n/a
2	80	M	Wet AMD and macular hole	6/60	6/38	n/a	n/a
3	85	F	AMD	6/19	6/210	n/a	0.8 M at 5 cm
4	93	F	Wet AMD	6/258	6/37	n/a	5 M at 15 cm
5	75	M	Dry AMD	6/30	6/95	n/a	1.2 M at 17 cm
6	77	F	Wet AMD	6/24	6/24	6/24	1 M at 20 cm
7	76	M	Dry AMD	6/120	6/24	6/24	0.8 M at 18 cm
9	78	F	Dry AMD	6/96	6/38	6/38	1.8 M at 20 cm
10	78	F	OD: AMD + Glaucoma; OS: glass prosthetic	4/20	None	n/a	1.25 M at 18 cm
11	69	M	Wet AMD	6/30	6/38	n/a	1 M at 25 cm
12	80	F	Dry AMD	4/40	4/20	4/20	1 M at 15 cm
13	84	F	AMD	6/96	6/48	6/48	n/a
15	65	M	Macular atrophy	6/120	6/120	6/120	n/a

Note. VA: visual activity; OD: right eye; OS: left eye; OU: both eyes; AMD: age-related macular degeneration; n/a: not available.

with a visual acuity between 20/60 and 20/200 (6/18 to 6/60) in the better eye with the best standard correction, according to the eligibility criteria for vision rehabilitation in Quebec, Canada.³⁸ Participants could not be undergoing surgical and/or medical treatment regarding their visual impairments. Their visual acuity had to be stable for the 3 months prior to the study, and they needed to be able to read and communicate in French or English. Participants were recruited through local vision rehabilitation centers in a large urban Canadian region. If they confirmed interest, the research team obtained preliminary information on the participants' experience with computer use and answered any questions about the project. The participants who remained interested in participating in the experiment were scheduled for an appointment to complete their testing session. They were compensated with \$25 CAN towards their travel expenses resulting from their participation in the study. Moreover, the presenting gender of our participants was identified based on their chart information.

The participants' demographic information can be found in [Table 1](#).

Materials and Testing Site

The testing sessions took place in a university research room without any distractions. The materials required for the completion of the protocol were two Apple iPad Air (2013), a tripod, and a reading stand. iPads were used in the present study because they were already owned by the research team. The first iPad was used for video and audio recording purposes and was mounted on the tripod. The second was used by the participant to complete the tasks on the AotB application and was placed on the reading stand.

Art on the Brain™ Application. Art on the Brain™ is an interactive art-based application that aims to bringing leisure activities into the home. AotB is a virtual art museum that

enables the user to interact with visual artwork through 3 different categories of activities: Learn, Play, and Mingle. The Learn feature allows the user to read and/or listen to the curatorial description associated with the selected artwork. The Play feature includes a series of 3 games: a word search game, a puzzle game, and a storytelling game. All games offered relate to the artwork that the user is currently viewing. For word search and puzzle games, the user can select the level of difficulty (easy, medium, difficult). In the Mingle feature, the participant can engage with a virtual community and share comments and stories about the artwork with the other users of AotB. Please note that the Mingle feature was not used in the present protocol. Mingle is designed for interactive use requiring repeat visits to the AotB virtual community. Here, we investigated a one-time experience of older adults with a visual impairment in order to understand how this product could be further optimized to function as an enjoyable and accessible leisure activity.

Tasks

Throughout the testing session, participants were asked to perform a series of tasks that were chosen as indicators of the usability of the application (6 categories regrouping a total of 13 tasks, see [Table 2](#)).

The tasks provided information on the proportion of participants that were able to complete each task action and if they could be completed without any help from the experimenter.

While coding the transcriptions, the tasks were categorized as "completed," "partially completed," "not completed," or "not applicable" (N/A). "Completed" was used when the participant completed the task by him/herself without needing any help. "Partially completed" was used when the participant completed the task but needed help in order to do so. "Not completed" was used when the participant was not able to complete the task. Finally, "not applicable" indicated that the

Table 2. Experimental Tasks Completed with the AotB application.

AotB Sections	Task's categories	Tasks	
Learn	Audio play-back	Find the audio button Understanding the audio description	
	Magnification of the artwork	Find the magnifying button Description of the artwork	
Play	Word clue game	Read the clue Find the answer in the text	
	Wordsearch puzzle	Read the word to find Find the word in the grid Trace the word in the grid	
		Puzzle	Complete the puzzle
		Storytelling	Find and select the location to start writing Write a sentence about the artwork Close the keyboard

Note. AotB: ArtontheBrain™.

task was not performed because of technical problems with the application or when the experimenter did the task for the participant before the participant could try it because of an administrator error.

Procedure

Prior to the participants' arrival, the iPads were fully charged and set to the highest luminosity and volume parameters. After obtaining informed written consent, the participants received instructions on how to use the iPad and could practice using it for a couple of minutes. The participants were then familiarized with the Learn and Play features of the AotB application and what they should expect to encounter during the session.

Once the participants were comfortable with the iPad and understood the AotB application involved activities focused on visual artwork, the researcher placed the recording iPad on the tripod behind and above the participants' shoulder. This was done to protect their anonymity while maintaining a visual on their interactions with the application. The second iPad was in front of the participant, resting on a reading stand adjusted to the participants' preference. The researcher made sure that there was no glare on the screen that would impair the participants' vision or that would make it impossible to see the screen on the video recorded by the other iPad.

Using the Concurrent Think Aloud method,³⁹ participants were asked to continuously comment on their experience with the application while being audio/video recorded. This method has proven successful for analyzing the usability of new technology in similar studies.⁴⁰ If at any moment during the use of the application the participant stopped voicing their inner monologue, the researcher reminded them to say out loud anything that came to mind. The first task was to interact with the *Learn* feature of the application. Participants were asked to find a button that would magnify the artwork, to find the button that would close the magnification, and to find the "audio" button that would begin the text-to-speech option of

the application to have the artwork description read out loud. The participants were also asked to describe the artwork based on the magnification and the description they heard. This was done in order to ensure the participants understood the description of the artwork. They were then asked to interact with the *Play* feature, where they would play all 3 of the games offered (word search, puzzle, and storytelling). In addition, participants were asked to select buttons (e.g., the "next" button) and read instructions and words out loud. The participants were encouraged to ask questions or to ask for help during the testing protocol; however, they were first encouraged to independently try their best before the researcher intervened. If, despite trying, the participants were not able to perform an activity, the researcher then helped the participant by giving hints or, if needed, by performing the task for them in order to move forward with the protocol. After completing all of the tasks within the *Learn* and *Play* activities, participants were asked to answer questions about their overall appreciation of the application and to point out any issue or difficulty they encountered while interacting with the application.

Moreover, the application has a gallery guide feature called *Ralph* who is a cartoon dog. *Ralph*'s role is to guide the user throughout their experience within the AotB application. *Ralph* pops up in the bottom right corner of the screen when the participants click on a new game to give instructions, and then disappears.

Data Analysis

The recorded sessions were transcribed verbatim and explored by members of the research team using qualitative thematic analyses.⁴¹ The data were extracted by two members of our research team. Both members identified codes using the open coding approach. This was done by identifying frequently stated and emphasized ideas or behaviors relating to the barriers and facilitators associated with the usability of the application. These were then separated into sub-themes and

overall themes as repeated patterns of codes emerged. This process underwent seven revisions before accepting the eighth and final coding scheme (see Appendix 1). Two members of the research team completed data coding and analysis separately, before meeting together to compare and agree upon the final codes, sub-themes and themes. A coding table was then collaboratively created. This initial separate data analysis was done to ensure an appropriate rigor of analysis was established, and to reduce personal bias.⁴² The completion of the tasks and the participants' answers to the questions were compatibilized in the verbatims by two members of the research team.

Results

Seventeen participants (10 women, 7 men) between the age of 65 and 93 years, $M_{age} = 78,24$, $SD = 8,84$, were recruited to participate in the study. Of these, data from only 15 were included for analyses (8 women), $M_{age} = 77,07$, $SD = 8,47$ (see Table 1 for further information).

Data for two of the participants were unusable; technical problems with the performance of the application interfered with data collection from one participant and another participant had difficulty following through on the continuous comment requirements of the protocol.

Overall, 30 codes were grouped into two overarching categories: Barriers and Facilitators. There are four sub-categories of codes within the Barriers (App Interface, App Function, User and iPad Interface) and two sub-categories within the Facilitators (App Features, App in general).

Barriers and Facilitators to the Usability of ArtontheBrain™ App

Category 1: Barriers. The barriers category regroups the codes used to describe elements of the AotB application that hinders the participant's ability to use the application or that prevents the application from being easily accessible for persons with

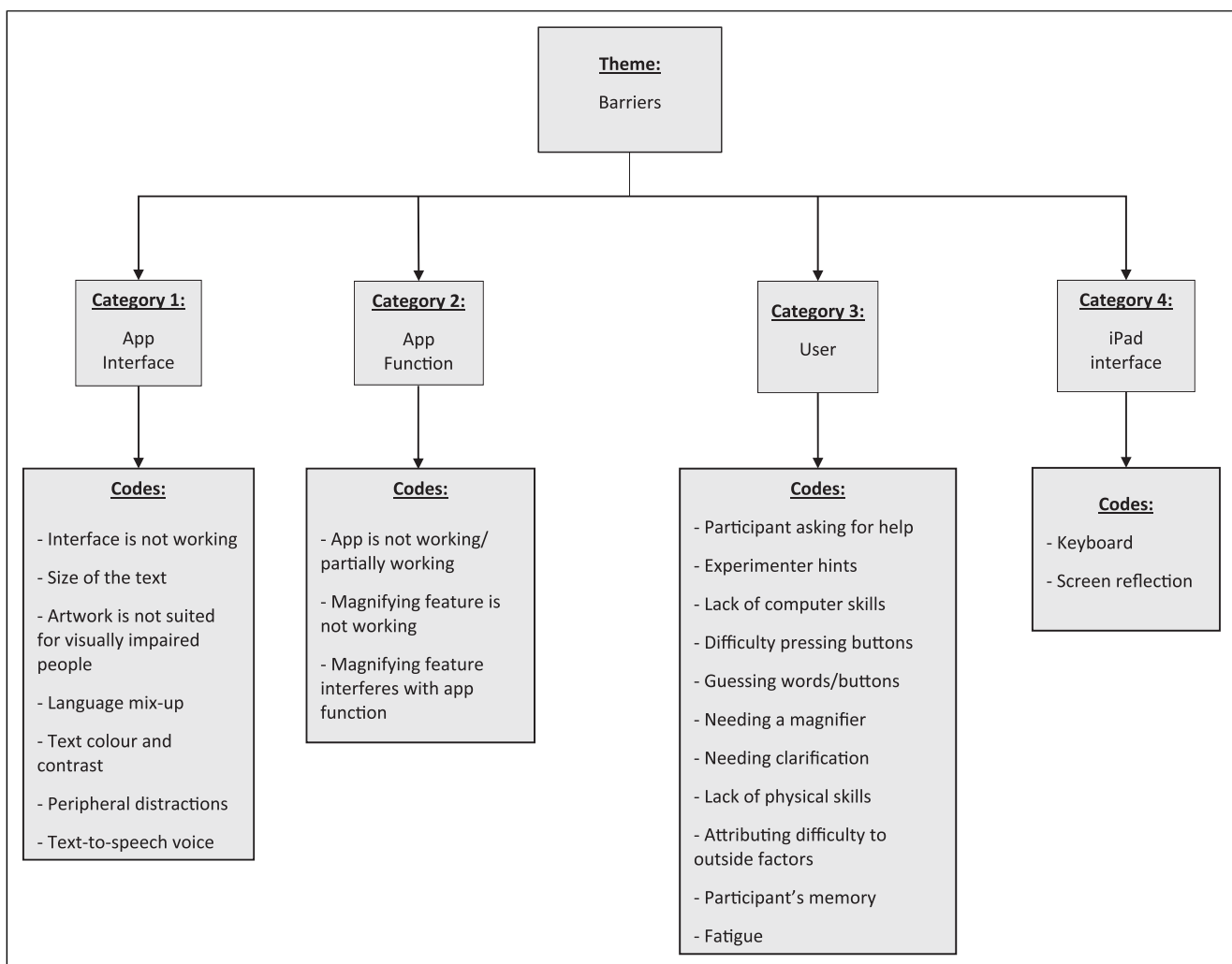


Figure 1. Coding scheme for the barriers to the usability of ArtontheBrain™ App.

LV. The four sub-categories are as follows: App Interface, App Function, User, and iPad Interface (see Figure 1). These facilitators concern both the *Learn* and *Play* sections of the application.

Sub-category 1: App interface. This sub-category contains every code in relation to the accessibility and usability of the application interface. It is closely linked to the user experience of the application and contains six codes. These codes were used in instances where the application interface was the reason for the participant's difficulty to use the AotB application, including: text size that is too small, poor contrast between the text and the background, distracting visual effects, or problems with the functionality of the interface. For example, participant #12 mentioned that "Me, what's causing me problems, it's the indications around. Sometimes, we have to press there, there, there" (she points to different locations where she had to click).

Sub-category 2: App Function. This sub-category regroups the barriers in relation to the functionality of the AotB application. It is closely linked to the programming of the application and contains 3 codes. These codes were used in instances where the application itself was malfunctioning or not functioning at all. The functionality of the application was the reason for participants' difficulty to use the AotB application. These instances include: application bugs, malfunction or interference of built-in features of the application with other functionality, crashing of the application and the entirety of the application is not working.

Sub-category 3: User. This category regroups the barriers in relation to the user. It highlights the characteristics of a sample of older adults with a visual impairment that prevent them from using and easily accessing the AotB application.

This sub-category contains 11 codes. These codes were used in instances where the user was the reason behind the difficulty to use the AotB application. These instances include: the lack of physical and/or computer skills to adequately use the iPad or the AotB application, the memory of the participant is not good enough for him/her to use the application alone, and the need for interventions from the experimenter to complete the tasks. For example, participant #2 mentioned as she was using the keyboard function on the tablet screen "[...] I can remember how to go back, and the trouble is, I see A B almost the A is like on top of the B on the keyboard. My macular degeneration does that to me."

Sub-category 4: iPad Interface. This sub-category regroups the barriers in relation to the technological device used during the study, in this case an iPad air 2013. It highlights aspects of the iPad interface that made it difficult for an older individual with a visual impairment to use the AotB application. This sub-category contains two codes. These codes are used in instances where the iPad interface was the reason for the poor usability and accessibility of the AotB application. These instances include: the keyboard that is not fitted for visually impaired persons as it is too small, can hardly be magnified and the letters are too thin, as well as the screen that is reflecting the light, even though the iPad was adjusted on a reading stand prior to the beginning of the protocol. For example, participant #15 had difficulties with the keyboard on the iPad screen: "There is one thing, the keyboard, the letters should be a little bit bigger, for me, they should be a little bolder."

Category 2: Facilitators. The facilitators regroup codes that are used to describe aspects of the AotB application that facilitate

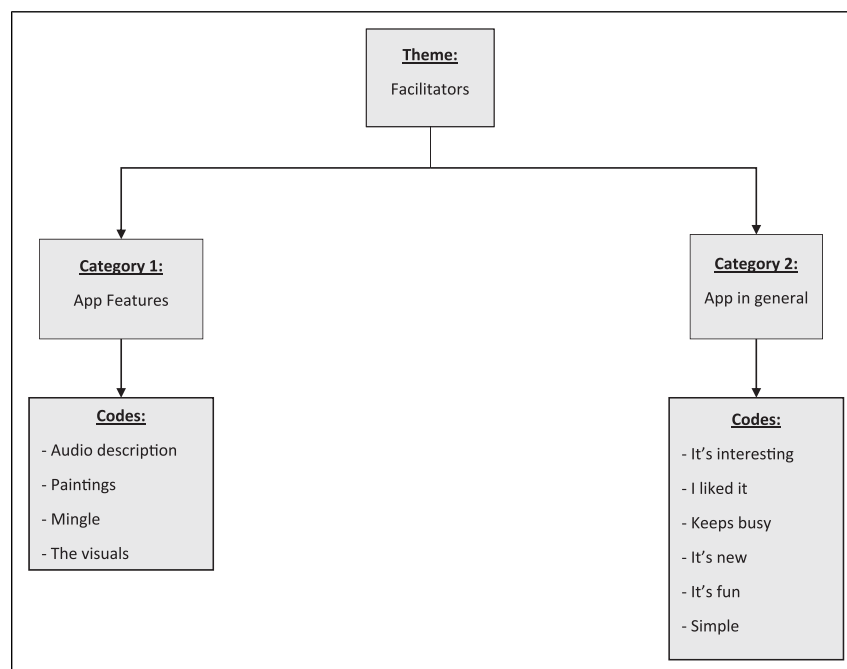


Figure 2. Coding scheme for the facilitators to the usability of ArtontheBrain™ App.

the use and accessibility of the application as well as aspects of the AotB application that are creating a more enjoyable user experience. The facilitators are divided into two sub-categories: App Features and App in general. These facilitators concern both the *Learn* and *Play* sections of the application (see Figure 2).

Sub-category 1: App Features. This sub-category regroups the facilitators in relation to the built-in features of the AotB application. It highlights the features of the application that facilitate the usability and accessibility of the AotB application for a sample of older adults with a VI. This sub-category contains three codes. These codes are used in instances where the built-in features of the application made it easier for the participants to discover the application as well as when these features enhanced the user experience. These instances include: the built-in audio description features that read the description of the artwork out loud, the magnifying feature that enlarges the texts and the artwork and the artworks themselves that are from renowned museums. For example, participant #15 mentioned that “*We are searching for questioning and giving our comments and composing little things. It’s good, I think it’s good that way.*”

Sub-category 2: App in general. This sub-category regroups the facilitators in relation to the feedback of the participants on the overall AotB application. It highlights what the participants liked about this particular application. This sub-category contains five codes. These codes are used in instances where the participants expressed favorable opinions about the AotB application. These instances include: liking the application in general, finding it interesting, fun and simple to use as well as liking that the AotB application keeps the user busy. For example, participant #10 mentioned that “*And I liked it because I understood pretty easily. It’s very simple.*”

Tasks

The information regarding the distribution of the tasks within the *Learn* and *Play* features of the application as well as the

information regarding the task categories can be found in Table 2. The information regarding the completion of the tasks is provided in Table 3. As presented in this table, for each task, most of the participants were able to complete them, indicating high usability of this first iteration of the AotB application.

Category 1: Audio Play-Back. The first task of this category was to find the “audio” button that starts the text-to-speech feature of the application. This feature reads the description of the artwork aloud. A total of 14 participants were able to complete this task. The second task of this category was to understand the audio description of the artwork. A total of 11 participants completed this task, two participants partially completed it and two participants did not complete it. Both participants who did not complete this task did not remember anything from the text that was just read to them.

Category 2: Magnifying Artwork. The first task of this category was to find the button to enlarge the artwork. A total of 12 participants completed this task, two participants partially completed this task and one participant did not complete the task. The second task was to be able to see the artwork after it had been enlarged. Participants were asked to describe the artwork. A total of 14 participants were able to complete this task and one participant partially completed this task.

Category 3: Word Clue Game. The first task of this category was to read the clue displayed on the screen. All of our 15 participants were able to complete this task. The second task was to find the word corresponding to the answer of the clue in the text. A total of 14 participants were able to complete this task and one participant partially completed this task. Solving the clues supplied the target words in the wordsearch puzzle.

Category 4: Wordsearch Puzzle. The first task of this category was to read the word to find in the letter grid. A total of 11

Table 3. Completion Frequency for the Experimental Tasks.

Tasks	Completed	Partially completed	Not completed	Not applicable
Find the audio button	14	0	1	0
Understanding the audio description	11	2	1	0
Find the magnifying button	12	2	1	0
Description of the artwork	14	1	0	0
Read the clue	15	0	0	0
Find the answer in the text	14	1	0	0
Read the word to find	11	0	2	2
Find the word in the grid	12	0	1	2
Trace the word in the grid	8	0	1	6
Complete the puzzle	14	0	0	1
Find and select the location to start writing	10	2	1	2
Write a sentence about the artwork	12	0	2	1
Close the keyboard	10	2	0	3

participants were able to complete this task, two participants did not complete this task, and this task was not applicable for two participants. The second task was to find the word in the letter grid. A total of 12 participants were able to complete this task, one participant did not complete it and the task was categorized as not applicable for two participants. Finally, the third task was to trace (highlight) the found word in the letter grid. A total of eight participants completed this task, one participant did not complete it and the task was not applicable for six participants.

Category 5: Puzzle. The only task for the puzzle was to restore the artwork image to its original form by re-arranging scrambled pieces of the artwork by moving the pieces to their correct location in order to recreate the artwork. A total of 14 participants were able to complete it and the task was not applicable for one participant.

Category 6: Storytelling. For this final category, the first task was to find and select the location on the screen to start writing. A total of 10 participants completed this task, two participants partially completed this task, one participant did not complete this task and the task was not applicable for two participants. The second task was to write at least one sentence about the artwork using the keyboard function of the application. A total of 12 participants were able to complete this task, two participants did not complete this task and the task was not applicable for one participant. The third and last task was to close the keyboard. A total of 10 participants were able to complete this task, two participants partially completed the task and the task was not applicable for three participants.

Discussion

The purpose of the present accessibility study was to gain a better understanding of the barriers and facilitators perceived by older adults living with LV when utilizing the ArtOnTheBrain™ application to access visual art. It is important to keep in mind that this study utilized the first iteration of the AotB application, and that further development is needed for this application to be fully usable by the general public.

Accessibility

The main findings regarding the barriers of the AotB application were that the interface was not currently fully adapted for older adults with LV (e.g., control over text size, contrast, and color of the text are now under development), there were problems regarding the application functionality, the participants were inexperienced with technology (e.g., they needed help from the experimenter), and there were problems with the iPad interface. For example, participants were not able to restart the application on their own. The main findings regarding the facilitators of the AotB application were that the app features enhanced the accessibility of the

AotB application, thereby improving the user experience with the application itself.

Barriers. Application interface. All of the barriers found in this study regarding the AotB interface were related to the LV of our participants. First, there were some remaining malfunctions (e.g., screen freezing and buttons not working) with the application interface. Of course, when the next iteration of the AotB application is fully developed, we expect fewer issues with the interface. For individuals with central vision loss, it was difficult to resolve even the smallest glitches and, when these malfunctions occurred, they needed help from the experimenter throughout the testing session. There were no error messages or instructions for the user to instruct them on the procedure to follow to resolve the technical issue. Having such instructions written in large font accompanied by an error message or a video tutorial about how to resolve technical difficulties is recommended to inform the user of the possible steps to take to fix the problem. It would also be helpful to have customer support available by phone.

The main concern with the AotB interface was the overall low accessibility for individuals with LV. The text size, color as well as the contrast of the interface were not suitable for individuals with AMD. Indeed, individuals with LV generally require a large text size and a text color and background color that allow for a high contrast (e.g., black or dark blue on white). These elements facilitate reading and visual search for information on the screen. For example, the current generation of the application includes a light green button with white text inside. These colors do not provide sufficient contrast, making it difficult for participants to read the word on the button. In the application interface, there were a lot of blank spaces that could have been used to enlarge the existing texts and icons. Using this unexploited space to do so is recommended in order to facilitate the visual experience for individuals with LV. Also, it would be important to select background and text colors that create a high contrast. These recommendations also apply for the login page that contained small font sizes.

Another accessibility problem was the visual clutter and peripheral distractions sometimes present in the AotB interface. As the participants are navigating throughout the application, Ralph, the virtual museum guide, suddenly appears in the bottom right corner. For individuals with LV, unexpected movement in their peripheral visual field can be distracting.⁴³ Also, most of the time, Ralph disappeared before the participant had the opportunity to read the instructions that accompanied his appearance, thereby creating confusion. Written large-print instructions that the user can control and dismiss would easily remedy this problem. Once participants are familiar with the application, they will most likely not need the instructions anymore. Therefore, Ralph could be a feature that can be turned on or off in the settings menu.

A last point to address is the choice of artwork featured in the application. For older adults with LV, it is difficult to

appreciate an abstract painting because the lines are often less defined and the whole image can be more blurred. During this study, our participants reported that they had more difficulties describing the artwork when it was an abstract painting. Therefore, adding a feature in the settings menu to allow the participant to select the artistic style may be useful for ensuring a user experience that is appropriate for their level of visual impairment.

App function. This first iteration of the AotB application is still in development and not yet available to the general public. Therefore, this section and its recommendations are specific to the beta version of the AotB application. We strongly believe that these recommendations could be broadly useful for application development in general, especially when the targeted population has a visual impairment. Because older adults with vision loss have a great deal of difficulty seeing information on the screen, it was almost impossible for them to try and resolve any malfunctions they encountered (e.g., restart the app). As previously mentioned, the app interface would benefit from having a tutorial addressing possible technical glitches/issues and the procedure to resolve them, available to watch prior to the application use, as well as IT support available by phone.

Another barrier was that the magnifying feature did not work on some occasions. For older adults with LV, this feature is of the utmost importance for the application, and it needs to work every time the user is interacting in the application. Therefore, making certain this feature is correctly and consistently working becomes a priority when wanting to include app users with sensory loss. This includes making sure that the magnifying feature is compatible with the device used by the participant (e.g., computer, Apple iPad, Android tablet), as well as the app interface itself, and does not interfere with any other feature in order to enable the user to fully experience the AotB application.

User characteristics. Throughout the testing sessions, many barriers encountered were inherent to the participants themselves, some of which were directly linked to LV while others were of a more general nature.

Low vision user barriers. Most of our participants asked for help at some point during the testing session for various reasons. These difficulties were closely related to their visual impairment because they were not able to properly read the instructions. Most of the participants were asking for confirmation before doing any actions within the AotB application. This was closely linked to the AotB interface barriers that were discussed previously. Additionally, even when the participants did not specifically ask for help, the experimenter sometimes needed to give hints and clarifications to the participants to ensure the smooth running of the testing session. As most of the hints were given for the participants to find the location of buttons or letters on the screen, enlarging the texts on the screen as well as the grid of the word search puzzle is recommended. In general, everything that could be enlarged (e.g., text, icons, and buttons) should be enlarged.

A prevalent problem for individuals with LV was that they guessed words or buttons. Given the difficulties with reading with LV and the effort involved, individuals with LV often read letter by letter.⁴⁴ Guessing words and/or buttons was a strategy many participants were observed to use in order to read faster. Sometimes, perceived letters appeared as one on top of the other and therefore participants needed to guess the content, which often resulted in errors. These observations further strengthen the recommendation to give app users better control over font type, spacing and size, contrast and the option of making text bold. Some participants overcame these limitations by using their hand-held magnifier in order to complete the protocol. Initially, all participants used the application without any assistive devices. However, after having a lot of difficulties, some participants asked the experimenter if they could use their hand-held magnifier. They were permitted to do so. On other occasions participants told the experimenter they would need their magnifier to complete the protocol. If they had their magnifier with them, they were permitted to use it. Other participants overcame these limitations by moving the screen at a different angle in order to avoid reflections and glare on the screen that was created by overhead lighting.

General user barriers. Some of our participants experienced difficulties with the touch screen interface that could be explained by age-related reduction in tactile sensitivity, cool finger tips, dry skin or due to some inexperience with tactile interface technology.⁴⁵ Some of these barriers can easily be overcome using rubber stylus in future experiments. Participants generally appreciated the text-to-speech function of the app; however, age-related changes in hearing at times interfered with audibility, a barrier that has previously been explored in older adults with LV when utilizing devices that generate speech.⁴⁶ In addition, at times, it was unclear to the research team whether participants were confused with protocol instructions because of an inability to see various items on the screen, or whether there were cognitive barriers present. Future studies could benefit from including a cognitive screening measure that is accessible for persons with vision loss, such as the blind version of the Montreal Cognitive Assessment⁴⁷ in order to be able to tease apart the influence of cognitive factors. In addition, a test establishing the participants' ability to perceive speech in noise, such as the Canadian Digit Triplet Test⁴⁸ may be useful in establishing possible problems with speech perception and the need for hearing support or a quiet environment for engaging with the app. Changes in both cognition and hearing have been linked to changes in vision, and therefore including these variables in any protocol that considers sensory-cognitive aging is advisable.^{14,15,49}

Facilitators. One of the most appreciated features of the AotB application was the audio description, as it made the application accessible for older adults with low vision due to AMD. As many of the games in the application require reading text paragraphs, this feature enhanced the user experience while

making the games accessible. The artworks available within the AotB application were generally liked by the participants. Having a diverse collection of artworks was important to ensure that the users can find artworks that they enjoyed, appreciated or were curious to discover for the first time. After completing the protocol and during the debriefing, many participants expressed that they liked the application and that it was interesting. They also said that it was fun and simple to use. Finally, some participants commented that the application kept them busy and entertained. It is therefore important to focus on these comments in the next developing stages of the AotB application.

For the coding scheme and selected data examples, please see Table 4, where participants' quotes are presented in *italics*.

Implications for Practice and Research

The present study is an example for the need of multidisciplinary collaboration when developing innovative approaches to therapeutic recreation. In this case, the expertise of app developers, rehabilitation professionals, specialists in vision

impairment and researchers with a focus on aging and accessibility contributed at various stages in the development of AotB. Using an integrated knowledge translation perspective,⁵⁰ the team members continue the development of this virtual recreation app that has already shown promise in improving self-reported wellness when used with older adults in long-term care.³⁷ The next steps include sensory accessibility adjustments (improved access to contrast and magnification features and audio files) as well as the refinement of a more user-friendly tactile interface for tablet computer users. Thereafter, its evaluation will focus on exploring its potential health benefits over time in older adults living with LV.

The present findings should also be considered in the larger context of application development, as this study provides insight pertaining to the needs of low vision individuals regarding usability and accessibility. For example, the current findings could be useful for the development of accessible and usable learning activities for individuals with low vision. Additionally, the current findings can inform the technology developers of accessibility and usability barriers

Table 4. Coding Scheme with Selected Examples.

Categories	Codes	Quotes
App interface	Interface is not working	<i>"Sometimes, this one doesn't work. I will just try it to see if... (tries, but the highlighting doesn't work). No, sometimes, it doesn't work, it does not highlight (highlighting is still not working)"</i>
	Artwork is not suited for visually impaired people	<i>"P4: The first look, it's very blurry, is it blurry? RA: Yes P4: There, there is a form, I don't know if it's a figure or..."</i>
	Peripheral distractions	<i>"I2: Me, what's causing me problems, it's the indications around. Sometimes, we have to press there, there, there (she points to different locations where she had to click)."</i>
	Language mix-up	<i>"P12: "Close!" RA: Exactly P12: They could have put it in French!"</i>
	Text color and contrast	<i>"P15: Well, ok. The color green, it's... well in any case, for my part, it seems that it could be, I don't know, another type of color RA: What color do you think could be better? P15: A color brighter than this green, you know? Maybe magenta, or a blue... maybe a dark blue to distinguish the text"</i>
App function	Size of the text	<i>"P2: the letters have to be larger in order for me to read a little better."</i>
	Magnifying feature is not working	<i>"RA: So now we can click skip all, and now we're gonna play a more traditional search game. (on screen zoom not working...) Okay, it's not working."</i>
iPad interface	Magnifying feature interfere with app function	<i>"P1: So, Japanese? Oh, okay alright. J... It didn't go (referring to the highlight feature when word is found). Oh, wait okay there. Here it is! (highlight not working) ... What am I doing wrong?"</i>
	Keyboard	<i>"P15: There is one thing, the keyboard, the letters should be a little bit bigger, for me, they should be a little bolder."</i>
App features	Screen reflection	<i>"P17: The application, nothing, the, the module I used, the iPad, hum... and I wrote this to iPad themselves, the screen reflection bothers me a lot."</i>
	Magnifying button Paintings	<i>"P2: I can see her (the lady in the painting) better now yeah." "P10: Monet, I liked a lot, I liked a lot his landscapes. I even had some framed."</i>
App in general	Audio description	<i>"P7: I like the voice that talks like that. It would be fun to have a computer like that."</i>
	It's interesting	<i>"P2: it makes me want to play some more, it's nice, it's interesting."</i>
	I liked it	<i>"P1: [...] I liked it yeah. Yeah, I really liked it."</i>
	Keeps busy	<i>"P11: it keeps the brain busy. It makes it think, it makes it work..."</i>
	It's fun	<i>"P1: What did I think? I thought it was a lot of fun"</i>
	Simple	<i>"I0: And I liked it because I understood pretty easily. It's very simple."</i>

(continued)

Table 4. (continued)

Categories	Codes	Quotes
User	Lack of computer skills	"RA: You need to dismiss the keyboard P1: How do you dismiss the keyboard? That's what I don't know"
	Lack of physical skills	"P2: [...] I can remember how to go back, and the trouble is, I see A B almost the A is like on top of the B on the keyboard. My macular degeneration does that to me."
	Difficulty pressing buttons	"P2: Learn... which is learn... here (unsuccessfully trying to select). Learn... what does this say."
	Participant's memory	"RA: You need to find the answer in the text that answers the clue you read. Do you remember the clue? P2: nope, what clue?"
	Experimenter hints	"P1: Oh, sorry. Hmm, it's not that, okay I don't see a button RA: Okay, I can tell you it's really close to the artwork."
	Participant asking for help	"P1: Can you make it a bit bigger?"
	Needing a magnifier	"RA: Now we will select the easy level P4: Easy? RA: Yes P4: I really need my magnifier."
	Fatigue	"P9: (Laughs—puts down the magnifier on the table) Ouf, it's really tiring, it's really tiring for me."
	Guessing words/buttons	"P1:..I just, I don't know where it is... (reading from screen)..Art on the Brain...maybe this? (touches web address)"
	Attributing difficulty to outside factors	"P5: Frankly, I was not always understanding because it seems like my hearing aid is not loud enough. So, let's say it was irritating me a little bit during... Perhaps too nervous a little."
	Needing clarification	"P13: I have to find what was the name of the Spanish musician? RA: The first name, yes P13: I have to find it here? RA: Yes P13: I have to look for the word "what" RA: Actually you need to look for the first name."

Note. Participants' quotes are indicated by the letter P followed by their identification number. RA stands for Research Assistant. *: The quote was translated by the research team from French to English.

and facilitators associated with a visual interface. Moreover, the current findings could also be used to allow the user to personalize the interface of open-source applications, for example. Personalization of the app interface would enable for more suitable and accessible applications.

Finally, the present research project emphasizes the importance of gaining patient's feedback and input when developing tools for specific populations. Indeed, as described in a 2017 narrative review,⁵¹ considering the patients' input allows for a better understanding of the lived experience of clinical populations, and therefore facilitates the use of more comprehensive approaches, both in research and clinical settings.

Limitations

This study comprises some limitations. First, the AotB application was used on an iPad only. The recommendations are therefore specific to this device and may vary if AotB is used on any other device (e.g., computer, Android tablet). Also, we did not take into consideration the time it took for each participant to complete, partially complete or not complete the tasks. Even if most of the participants were able to complete the tasks, it is important to address the identified barriers of the application in order to facilitate the completion of the tasks and

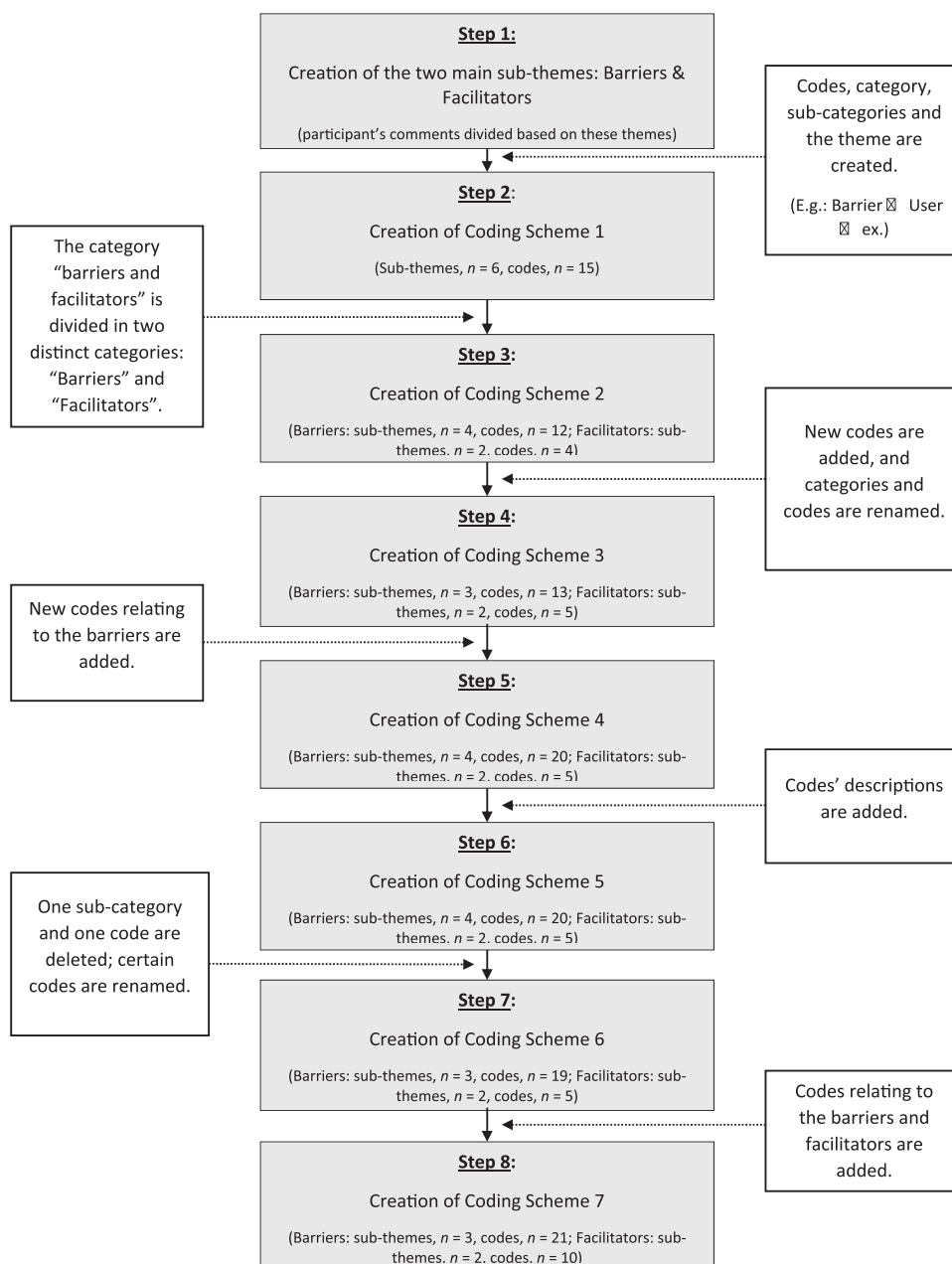
ensure the tasks can be completed in an acceptable amount of time. If the tasks take too long to perform because of the previously mentioned barriers, this could lead to a high level of abandonment of the AotB application. Finally, we only recruited participants with AMD. Therefore, we cannot definitely conclude the results would generalize to other visual impairment causes, such as glaucoma or diabetic retinopathy, given differences in how central vision may be affected.

Conclusion

The ArtontheBrain™ application has the potential to make visual art accessible and available for individuals that are otherwise unable to access museum spaces physically or for other reasons that pose accessibility barriers. The present study forms the starting point for overcoming these barriers as they exist for persons with a visual impairment and highlight the need to consider visual accessibility in the development and realization of web-based resources like ArtontheBrain™. The current context of physical distancing has placed increasing importance on tele-access alternatives, and leisure activities are no exception. Improved and expanded versions of ArtontheBrain™ are currently under development, with the goal of becoming more universally accessible and available to all.

Appendix I

Annex I. Step-wise development of the coding scheme.



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